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Memory and the Human Lifespan

Course Guidebook

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Professor Steve Joordens is Professor of Psychology, Associate Chair of Psychology, and Program Supervisor for the undergraduate program at the University of Toronto Scarborough. He received his undergraduate degree in Psychology from the University of New Brunswick and his master's and doctorate degrees in Cognitive Psychology from the University of Waterloo. After a brief postdoctoral fellowship at McMaster University, he joined the faculty of the University of Toronto Scarborough in 1995.

Professor Joordens's research includes developing and implementing technologies for learning. His innovation was honored when he and his Ph.D. student Dwayne Paré received a National Technology Innovation Award in 2009 for the creation of peerScholar (www.peerScholar.com), an Internet-based educational platform that supports the development of critical-thinking and communication skills in a classroom of any size. Through work conducted in his laboratory, he has published high-quality research related to teaching, learning, and the use of technology. Some of this work documents the functional and pedagogical validity of peerScholar, and some examines the use of technology to enhance traditional lectures.

More recently, Professor Joordens and his colleagues have been investigating the effective use of mobile applications as cognitive prosthetics to assist both the learning disabled and patients with Alzheimer's disease. This work has been presented at a range of international conferences and consistently wins "best in session" honors. In recognition of his work, he was invited to be a speaker for the Teaching of Psychology Section at the 2010 Canadian Psychological Association Convention, and he often gives keynote addresses at conferences related generally to effective teaching or specifically to the effective use of technology.

Professor Joordens continues to conduct research on human memory, consciousness, and attention and has many publications on these topics in top-rated empirical and theoretical psychology journals. This research has been consistently supported by grants from the Natural Sciences and Engineering Research Council of Canada. In recognition of his work on memory, Professor Joordens won a Premier's Research Excellence Award for the 2001–2006 period. The research relevant to this work provides the underpinnings of his more recent research on the effective use of technology to promote learning.

In addition to being recognized for his research and innovation, Professor Joordens received the Scarborough College Students' Union's Best Professor Award for 2002–2003 and 2010–2011. He has been nominated 4 times for Television Ontario's Best Lecturer Competition—once making the Top 30, once making the Top 20, and twice making the Top 10 list. He also won a provincially sponsored Leadership in Faculty Teaching Award in 2006–2007 in recognition of both his lecturing and his innovative approach to education. In 2010, Professor Joordens's teaching accomplishments were further recognized with a President's Teaching Award, the highest award for teaching at the University of Toronto. Along with a yearly research grant, this award makes Professor Joordens a member of the university's Teaching Academy, a group of 25 or fewer faculty who promote teaching initiatives and generally strive to enhance the learning experience for all students at the University of Toronto. ■

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SUPPLEMENTAL MATERIAL

Memory and the Human Lifespan

Scope:

Our memory allows us to remember and share past events, to function efficiently and intelligently in the present, and even to predict and prepare for the future. It is truly amazing that we can mentally relive events that occurred decades in the past. And yet this amazing memory system is also prone to failure, sometimes with embarrassing social consequences.

The goal of this course is to provide a rich and complete description of the cognitive and biological bases of human memory and to describe how they come together in everyday life. First, we shatter the illusory notion that memory is a single thing. In reality, influences of the past are carried forward by a number of different cognitive processes, each of which can be thought of as a distinct memory system. How we remember events of our lives differs from how we retrieve general knowledge about the world and how we remember a specific routine or skill. Each of our memory systems differs from the others in purpose and character, yet they also interact in complex and fascinating ways.

After a general introduction, the course begins with lectures on 2 techniques that have been used to enhance memory: ancient "art of memory" techniques, which date back to classical civilization, and rote memorization, which was central to the first scientific investigation of memory.

Subsequent lectures describe our various memory systems, including those that support our long-term memories of events (episodic memory), facts about the world (semantic memory), and skills we have learned (procedural memory). Short-term memory systems are also presented, including sensory memory systems and perhaps the most interesting and multifaceted memory systems, working memory. We also look at implicit memory, a system that allows us to learn and use the regularities of the world without even trying to learn them.

Sometimes these different memory systems work together, but sometimes they work at cross-purposes, and we'll take a look at situations in which habits, supported by procedural learning or implicit memory, can conflict with goals and produce unwanted behaviors. The importance of sleep to memory consolidation will also be highlighted, and we consider the extent to which our memory systems are, and are not, uniquely human. In addition, the development of memory systems in human infants is described.

Clearly, memory occurs in the brain, and we consider the links between brain systems and behavior both in intact memory systems and in various forms of brain damage, like the amnesias. Our understanding of memory and the brain has already been transformed by brain-imaging techniques such as functional magnetic resonance imaging; we'll look ahead to how attempts by some intrepid researchers to model brain systems using computer-based, artificial neural networks may offer further insights in the future.

With this scientific understanding of memory systems in place, we then consider the way these systems interact to produce important memory phenomena that influence us every day with or without our awareness. We consider the powerful influence of the simple repetition of experience, and in so doing we gain a better appreciation for why, for example, political candidates love seeing their names posted in every corner of your neighborhood. We visit the phenomenon of déjà vu as an illusion of memory to see what it might tell us about interactions of memory systems. We also consider the empirical evidence that it is possible to create false memories and the implications of this research for the controversy over recovered memories.

One critical point we will develop is that conscious memories are actually reconstructed, not simply retrieved, and that our conscious (i.e., episodic) memories are really created by weaving together accurately recalled information with the thread of semantic memory—things we simply know to be true of the world and thus assume to be true of new episodic memories. Within this framework, we must ask which details are accurately retrieved and what we might do to maximize the likelihood of accurate retrieval. In fact, we'll go over some clear tips for doing just that.

Other lectures focus on memory later in life in both Alzheimer's disease and normal aging. We consider the impact of Alzheimer's disease on caregivers as well as patients, taking care to distinguish early-stage Alzheimer's from normal changes during aging. We discuss factors that may help prevent Alzheimer's, look at research into cognitive prosthetics aimed at enhancing quality of life, and consider the overall implications of this devastating disease for our understanding of memory. We discuss how the changes of normal aging are often exaggerated, and we situate the real but small memory deterioration that does occur in the context of a broad cognitive transition, highlighting approaches for taking advantage of the transition while minimizing the deterioration.

Overall, the course describes the complex role that memory systems play at all stages in our life and highlights how critical these systems are for providing our sense of self. After all, who we are is ultimately defined by the experiences we have had, the things we know, and the skills we have acquired through life. Every aspect of who we are is embodied in memory systems, a better understanding of which can greatly enrich our lives. ■

Memory Is a Party

Lecture 1

Before we begin exploring human memory, we have to define what memory is. Rather than being a single entity, human memory is made up of multiple systems that interact in various ways. This complexity underlies both the power and fallibility of memory.

Human memory is truly amazing. Most of us can probably recall several strong decades-old memories. But memory can sometimes fail us, too. In fact, sometimes it can succeed and fail at the same time. How can the same system be simultaneously so amazing and so prone to error?

In a sense, we'll be answering that question throughout the course, but the short answer is, there is no single thing called memory. In fact, memory isn't really a "thing" at all but a group of cognitive processes that interrelate in complex ways.

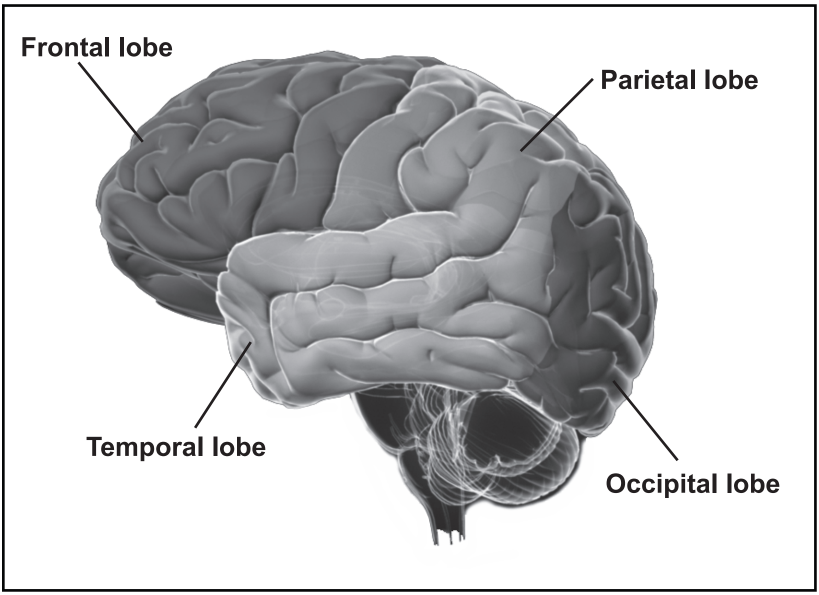
The brain is divided into cortical regions and subcortical regions. The subcortex consists of small areas like the hippocampus and the amygdala that are critical for creating memories, especially emotional memories. It also comprises larger regions, like the whole cerebellum, which is involved in memory related to motor activity.

The cortex consists of 2 hemispheres of 4 lobes each, with a web of nerve fibers called the corpus collosum connecting the hemispheres. Three of each hemisphere's lobes analyze signals coming in from the world—seeing, hearing, and touching—and the fourth lobe, the frontal lobe, handles attention and self-control.

Memories involve a lot of coordination between the higher brain regions of the cortex and lower brain regions such as the hippocampus. Our memorial abilities actually reflect the orchestrated interaction of a number of different memory systems. Let's use some examples to look at the different memory systems.

If someone asks you, “What did you have for dinner last night?” that episode of your life likely replayed like a little movie in your mind; this is **episodic memory**. However, if someone asked you to calculate 5 times 4, it would probably feel like the answer just appeared, unaccompanied by an event. This is **semantic memory**, memory of facts you have learned about the world, detached from memory of an event or episode; your repeated exposure to this information has decontextualized it. Thus there seems to be a continuum between episodic and semantic memory systems.

The smooth and accurate performance of a physical routine—an athletic maneuver or dance number, for example—is the result of effective and repeated practice. The performer is using **procedural memory**, also called muscle memory, because the relevant muscles have learned how to orchestrate themselves. Procedural memory is also part of how we learn to speak a language fluidly. Learning words is an act of semantic memory,



The 4 lobes of the brain are associated with different functions.

but the appropriate reproduction of sounds by the muscles of the throat is procedural memory.

From these examples, we can broadly define memory as any time when a past experience has an effect on current or future behavior. It doesn't matter whether or not you are trying to retrieve information from the past; whether the past affects the present is all that matters.

The memory systems we have discussed so far all belong to a general class called long-term memory. Other systems hold onto experiences for a short time, usually just long enough to accomplish some task.

Sensory memory is a fading copy of some stimulus that has impinged on our senses. For example, if someone asks you a question while you're thinking about something else, you might have said, "What?" But as the person repeats the question you say, "Sorry, never mind. I heard you." You stored the question in your sensory memory—specifically, your echoic memory—for a few seconds then replayed it.

Working memory, sometimes called short-term memory, allows you to hold a memory briefly until it can be used in some other way. A common example is repeating a phone number over and over while hunting for a paper and pen to write it down.

Working memory also plays a central role in the ability to combine information from other memory systems, often with the goal of solving some novel task or problem. When you gather information from various types of memory—episodic, semantic, and so forth—your working memory is where you process it, an act we tend to identify as conscious thought. ■

Terms to Know

episodic memory: Memories of specific, individual events, as opposed to general knowledge.

procedural memory: The body's mastery of a physical routine; often called muscle memory.

semantic memory: General knowledge about the world learned through repeated exposure to the information, as opposed to memories of specific events.

sensory memory: A temporarily retained impression of a sensory stimulus.

working memory: Sometimes called short-term memory, a memory system used for both temporary storage and as a mental workspace where information from other systems is processed.

Suggested Reading

Baddeley, *Essentials of Human Memory*.

Howard, *Learning and Memory*.

Loftus and Loftus, *Human Memory*.

Questions to Consider

1. How does the psychological definition of memory differ from the way you thought about memory before watching this lecture?

2. If you had to lose the use of just one memory system, which one would you choose to lose and why?

Exercise

Over the course of about 15 minutes, take note of how often you use memory to accomplish specific tasks and which memory systems you use.

The Ancient "Art of Memory"

Lecture 2

Human beings have long pursued the "art of memory"—that is, developing and implementing techniques to enhance recall. The most successful of these so-called mnemonic strategies highlight the connection between strong encoding and successful retrieval through the techniques of organizing, associating, and dual coding.

It is possible to improve memory, but many books on memory improvement never address the issue of multiple memory systems. Usually, people are looking to improve their episodic memory—their ability to remember new bits of random information.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The ROY G. BIV acronym for remembering the colors of the rainbow is an example of multiple encoding—each color is associated with a letter, and the letters are encoded as a name.

Let's start with a demonstration: Given a list of 14 unrelated words, my task is to remember those words in order over both a short and long time period. I can connect these words to a set of words that are meaningful and related to me. This is called the **method of loci**. ("Loci" is the plural of "locus," a Latin word meaning "place.")

The method of loci dates back to the great orators of the Roman Empire, who used it to demonstrate the accuracy and reliability of their memories (and thus of the news they brought from Rome to the far-

flung provinces). They would associate the names of high-ranking listeners with familiar locations along their routes. This provided both associations between the familiar and unfamiliar and an organizational structure.

Often when people say they can't remember something, they are implying that the problem is with memory retrieval. Technically this is true, but our ability to remember something depends on the way we think about the information when we first encounter it—that is, on how well we encode it.

Research shows that we remember bizarre things better than we remember common things.

Organization at the time of encoding is the first critical variable that we can learn to use to enhance our memory. When you use the method of loci, you take the time to attach each new piece of information to a structure you already have in memory. This might be a list like the alphabet, the order of your morning routine, landmarks along your commute to work, and so on. You are using the familiar information to get to the right "area" of memory. Working memory is the system we use when bringing together information from the outer and inner worlds in this way.

Forming good associations is the second critical variable we can use to enhance our memory. Research shows that we remember bizarre things better than we remember common things. Turning each word into a picture also helps by making a sort of copy of the word: The word form is stored in the part of the brain that deals with linguistic stimuli; the picture form is stored in the part of the brain that deals with images. Psychologists call this **dual coding**.

Virtually all mnemonic strategies use organization, association, and dual coding in some manner. For example, in using the acronym ROY G. BIV to remember the colors of the rainbow, the name provides organization, the use of the first letter of the color word provides a strong associative link, and thinking of colors in terms of a name provides dual coding.

Unfortunately, many personal names do not lend themselves well to imagery, and that's partly why they are so hard to remember. Your best bet is to try multiple tricks. Some will be just playing around with words or well-known slogans, or you can search your memory for the most similar name you've ever heard. The more you know or notice about the person, the more possible connections you can make.

By using strong organization, forming good associations, and utilizing multiple codes when possible, your memory performance will improve. If you do all these things over and over, then it will become natural to put things into memory this way, so the effort involved will decrease. ■

Important Terms

dual coding: The process of relating a new piece of information we wish to remember with both an image and a word to increase the ways we can retrieve the information later.

method of loci: A memory-encoding technique that relates an unfamiliar set of data to a familiar set of connected data, the most common example being places along a route; by recalling the familiar information, we can quickly bring to mind the new information.

Suggested Reading

Foer, *Moonwalking with Einstein*.

Haberlandt, *Human Memory*.

Higbee, *Your Memory*.

Lorayne and Lucas, *The Memory Book*.

Questions to Consider

1. In this lecture, organization, association, and the forming of images were highlighted as factors one can use to enhance episodic memory. Why might we remember images better than words?

2. If it's possible to improve our memories, why doesn't everyone do it?

Exercise

Using the method of loci, create your own "memory palace" using places from your own life. As you do this, don't just create a list of place words; also take time to form a concrete image associated with each of your places. For example, if you were going to choose your house as a memory palace, actually walk through the rooms of your house in some specified order and take the time to really see each room. What things are in that room that you might later associate new concepts with? Maybe there is a piano in one room, a table in another, and so forth. The more you can enrich your image of each room, the easier it will be to subsequently associate things with that room.

Once you have your palace strong in your mind, mentally run through its locations at least once a day for a week, ensuring that this list is strong and easy to remember. Once your palace is firmly established, try using what you've created to remember a random list of words. Maybe write them out in the morning, commit them to your palace, then go about your day without further review. At the end of your day, try recounting the list of items. I bet you will be surprised at your success. It really works!

The next step is to use your new skill for something more practical. Maybe start with grocery lists and go from there.

Rote Memorization and a Science of Forgetting

Lecture 3

All art of memory methods require expending most of your effort up front, when you first encounter a piece of information. But traditionally, people have memorized general knowledge through repetition—rote memorization. Rote learning requires more ongoing effort but less extreme effort at any given time.

Rote memorization is interesting for 2 reasons. First, it has an interesting past and present and, to some extent, provides a great basis for comparison with art of memory strategies. Second, it played a key role in the birth of a true science of memory, in that it was the subject of the very first scientific memory experiments.

Rote learning and mnemonics almost seem like opposites. Mnemonic strategies require plenty of up-front effort, but thereafter the memories are retained rather effortlessly. By contrast, rote learning requires more sustained but less intense effort. Mnemonics are associated with episodic memory, whereas rote memorization is more strongly associated with semantic memory.

Repetition of facts might occur within some specific context, such as when a teacher drills us on multiplication tables, or we might have heard the same fact repeated across different contexts, like multiple people calling Florida the Sunshine State. If we do hear something enough, it becomes committed to our semantic memory, and over time we may forget the specific context in which we heard it. This is why politicians and political parties use talking points, so the same message is heard again and again across a variety of news formats.

Rote learning is probably quite ancient; we know that today's most important religious texts were originally transmitted orally, because there were few copies of the texts in existence. In Victorian Europe, rote memorization skills were regarded as evidence of a strong work ethic and strength of character. Rote memorization remains part of our education system.

Virtually all of the earliest psychologists studied perception, but German psychologist Hermann von Ebbinghaus published the world's first scientific study of memory, *Memory: A Contribution to Experimental Psychology*, in 1885. Using himself as a test subject, Ebbinghaus measured the time it took to learn, forget, and relearn a list of 2000 nonsense syllables using rote memorization. He ultimately produced a mathematical function called the **forgetting curve**.

Ebbinghaus's main discoveries were that memory decays exponentially, with most of the losses occurring right away, and that meaningless syllables were more quickly forgotten than meaningful words. Memory for real-world

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Facts learned through rote memorization, such as the multiplication tables, are stored in semantic memory.

experiences is likely not this dramatically affected, as we tend to process stimuli in a deeper, more meaningful way.

Subsequent research has suggested a number of reasons why we forget, or at least fail to recall, information. Sometimes we don't encode it well enough in the first place. Interference theory suggests that similar experiences, either before (**proactive interference**) or after (**retroactive interference**) you try to encode a memory, can interfere with encoding and recall.

Retrieval failure holds the most promise as a general explanation for memory failure; this occurs when memories are encoded without good retrieval cues and more recent memories seem to bury it in one big pile of information. The theory of retrieval failure fits Ebbinghaus's discovery that it was faster to relearn information than to learn it. His findings also support a distinction between conscious and unconscious or subconscious knowledge.

Both mnemonic techniques and rote memorization can be useful at the same time. Consider actors learning their parts for a play: They must learn very specific lines and movements. They could use their positions as location cues associated with a trigger word carrying the gist of the appropriate line, but rote learning might be best to memorize the lines themselves. We can use this combination in everyday life as well. In general, a key to creating a very lasting memory is to use more than one memory system. ■

Important Terms

forgetting curve: A mathematical function that predicts the time required to memorize, forget, and re-encode a set of data through rote memorization.

proactive interference: A previous experience that prevents successful encoding or recall of a similar piece of information.

retrieval failure: Forgetting; that is, when we cannot recall a piece of information, usually because it was encoded without good retrieval cues.

retroactive interference: An experience that weakens the encoding or recall of a previously memorized piece of information.

rote memorization: Memorization through repetition.

Suggested Reading

Ebbinghaus, *Memory*.

Herrmann and Chaffin, *Memory in Historical Perspective*.

Questions to Consider

1. List some contexts where you think rote memorization might be the best way to learn and remember. What, if anything, do those contexts have in common, and how widely do they differ from one another?

2. Why do you think Ebbinghaus's research failed to spawn a rigorous investigation of memory?

3. On another shopping trip, try learning your grocery list by rote. Don't think about it deeply, just repeat the items to yourself over and over.

Sensory Memory—Brief Traces of the Past

Lecture 4

Sensory memory is a short-lived memory buffer that retains sensory stimuli for a brief period, giving a person time to switch attention to the new stimulus even though it is no longer present. Whatever our conscious mind may be engaged with, we seem to be constantly storing incoming visual and auditory information and, at some level, processing it for potential importance.

Perhaps you or someone you know has the ability to focus on a task to the point where the rest of the world drops away. This is an extreme example of human single-mindedness; that is, people find it hard to consciously think about more than a single thing at a time. We're all familiar with the idea of multitasking, but the truth is that most evidence indicates we're not actually doing 2 things at once; we're switching our attention rapidly between the 2 or more tasks.

Rapid attention switching is made possible by our sensory memory, which acts like a very short-lived memory buffer, retaining a sensory stimulus (a sight, sound, smell, taste, or feeling) for a brief period after it occurs. This buffer gives us the time to switch our attention; more importantly, it maximizes the likelihood of us catching important stimuli when focused on something else.

The basic principle of this sensory memory buffer is straightforward, at least with respect to visual and auditory stimuli. (Little research has been done on the other senses.) A copy of the stimulus is briefly retained, giving us enough time to switch our attention and then process the copy. Switches of attention happen quickly, so the copy doesn't have to be saved for very long.

The visual form of sensory memory is called **iconic memory**. It is related to the persistence of vision—the phenomenon that makes a series of still pictures running through a movie projector imitate continuous motion and causes a light attached to a bicycle wheel to leave a trail as the wheel is

spun. The buffer of our iconic memory allows the light to live on in a certain spatial position even after the light source has moved on.

Iconic memory was first studied in detail by psychologist George Sperling in the 1960s. He used a device like a film projector, called a tachistoscope, to briefly show grids of letters to his subjects and measure how much they could recall and for how long. His results indicated that the subjects saw every letter in the grid initially, but the memory only lasted about 1 second—only long enough for subjects to specifically recall half of them. So the raw iconic memory fades quickly, but some part of the information can be transferred to another system, likely working memory. In fact, it seems that that purpose of iconic memory is to keep the raw image around in case some components of it are important.

Sensory memory—iconic memory in particular—also plays a role in keeping our sensory representations of the world intact and rich. Our eyes take in a scene not all at once but in 200-millisecond bursts called **saccades**. Each one gives us a snapshot of one part of the world; our iconic memory buffers allow us to piece these together like a mosaic. Our sense of hearing also has this sort of short-term memory storage, called **echoic memory**. Formal experiments indicate that echoic memory lasts for about 4 or 5 seconds, much longer than iconic memory, which is likely why we notice it much more.

Scientists think echoic memory lasts longer than iconic memory because of the importance of speech to human functioning. Speech is serial, with one word following another. We need to remember a whole sentence to process its meaning accurately; therefore, we need to hold words in our memory for several seconds at a time. Visual information does not have the same structured unfolding over time.

Do our other senses have short sensory memories as well? For taste and smell, the answer seems to be both yes and no. Smells and tastes do not suddenly appear and suddenly disappear; the natural fading of olfactory chemicals and the span of time food spends in our mouths gives us plenty of time to switch our attention to them. **Tactile memory**, or **haptic memory**, allows us to feel a touch gradually fade away as well. ■

Important Terms

echoic memory: The ability to hold or recall a sound in one's mind; the auditory form of sensory memory.

iconic memory: The ability to hold or recall an image in one's mind; the visual form of sensory memory.

saccades: Swift glances moving from object to object in a scene that our iconic memories use to piece together a whole.

tactile memory (a.k.a. **haptic memory**): The lingering impression of something we have touched or been touched by; a form of sensory memory.

Suggested Reading

Braisby and Gellatly, *Cognitive Psychology*.

Foster, *Memory*.

Luck and Hollingworth, *Visual Memory*.

Questions to Consider

1. When a dog goes outside, it smells lampposts and such because doing so tells the dog which other dogs have been there and when. How is a dog's sense of smell like human sensory memory? How is it different?

2. What if iconic memory lasted for 10 seconds and echoic memory for 30 seconds? Do you think that would be better? Can you imagine ways it could be problematic?

Exercise

Pay attention to what happens when you speak to someone who is deeply focused on something else. When they ask what you said, wait for a bit, and see if they realize what you asked without you repeating it.

The Conveyor Belt of Working Memory

Lecture 5

Working memory is a collection of mental processes that allow us to work with information, often to solve some problem. These processes can also be used to keep information "in mind" for a brief period; doing so, however, takes effort and is vulnerable to interference. Working memory is also limited in capacity, and that limit seems to determine how richly we can think about things.

Working memory plays a critical role in nearly everything we do. Pioneering psychologist William James called it primary memory, while he referred to everything we now call long-term memory as secondary memory. But working memory is much more than a memory system; in fact, it may literally be the part of our minds where "I" exists and interacts with our mental worlds.

Brain studies have shown that many areas across the cortex can be activated in support of working memory depending on the task at hand. The prefrontal cortex, for example, seems to maintain attention and manage distractions to make working memory more effective.

Working memory has 2 basic functions: First, it keeps information from fading away for short periods of time. Second, it is the gateway for putting information into long-term memory. In this lecture, we'll look at the first function.

Making and exploring mental re-creations is what psychologists call using the **visual-spatial sketchpad**. This part of working memory can deal with numbers, words, and images. Mentally reciting words or numbers to hold them in memory is also a function of working memory; that internal voice is called the **phonological loop**.

How long can working memory keep information alive? That depends. If you kept repeating a list of items to yourself forever, you could keep them alive forever, but you wouldn't be able to do much else. The main reason

things leave working memory is because we need to stop the repetition to think about something else. Thus, working memory is very fragile and easily disrupted.

Do things disappear from working memory by fading over time, or do they get pushed out by the new information? This is not an easy question to answer, but most evidence points to the latter—that older information gets pushed out of memory like items on a conveyor belt. Time is not the important factor; rather, the number of intervening items is most important.

A person's working memory capacity has been shown to correlate with his or her intelligence.

All this implies that working memory can only hold so much information at any given time. This raises some obvious questions: What is the working memory's capacity, can it be increased, and is increasing its capacity important or useful for daily functioning? Psychologist George Miller has found that humans, on average, can hold 7 items, plus or minus 2, in working memory at any one time. Across a number of studies, a person's working memory capacity has been shown to correlate with his or her intelligence and successfulness. This makes some sense, as a greater working memory capacity enables you to hold more relevant data in mind from which to make any decision, and thus the more accurate you would expect those decisions to be.

Can you increase the capacity of your working memory? In a sense, you can, if you can learn to chunk several bits of information into a single item. For example, you can think of the individual string of numbers 7, 4, 7, 1, 4, 9, 4 as seven bits of information, or you can use mnemonic strategies to remember them as "airplane" (747) and "Columbus" (1492). Now there are only 2 pieces of information to remember—and room for a lot more. So it's not the amount of information per se; it's the number of chunks that sets the limit for working memory. ■

Important Terms

phonological loop: The ability of the working memory system to recall and repeat a sound; one's inner voice.

visual-spatial sketchpad: The ability of the working memory system to re-create and explore a place or object in iconic memory.

Suggested Reading

Baddeley, *Working Memory, Thought, and Action*.

Gilhooly and Logie, *Working Memory and Thinking*.

Vandierendonck and Szmalec, *Spatial Working Memory*.

Questions to Consider

1. Imagine you could only hold 2 pieces of knowledge in your mind at any given time. How far do you think you could get on the "How high you could reach sitting on a camel?" problem?

2. Imagine you had an intact working memory for the first 16 years of life and then it stopped working. What would life be like? Would it be like you are a zombie who could only react to things in an automatic or habitual manner? Or would it be that you just didn't seem very smart?

Exercise

One of the challenges at the World Memory Competition requires contestants to learn the order of the cards in one or more shuffled decks. To do this, contestants use chunking in combination with some of the mnemonic techniques described earlier. The chunking typically works like this: Before trying to remember the order of cards in a particular deck, contestants first practice associating 3 cues with each card: a person, an action, and a place.

Coming up with vivid and distinct items for each card is key. Maybe the jack of hearts would be Prince William, his activity might be polo playing, and his location might be the Mall in London. The queen of hearts might be Angelina Jolie, adopting a child, and the Hollywood sign; the king of clubs might be Tiger Woods, riding a golf cart, and a golf course in Scotland. Competitors do this for all 52 cards; then, during the competition, they use this information to chunk 3 cards into one image. So, for example, if the first 3 cards in the deck happened to be the queen of hearts, the king of clubs, and the jack of hearts, one could imagine Angelina Jolie riding a golf cart along the Mall.

Try it! If you cut a deck down to just 20 or 21 cards (e.g., start with the 10, jack, queen, king, and ace of all 4 suits) and create and remember 3 aspects of each card (name, activity, place), you can impress your friends at your ability to remember the precise order of all 21, which of course will be just 7 chunks.

Encoding—Our Gateway into Long-Term Memory

Lecture 6

Encoding is the gateway where your present communicates with your future. One of the major functions of working memory is to perform this encoding in a way that makes memory retrieval easier. If you take time to use it correctly, working memory can even encode information in ways that cue you to remember that information at a specific time.

The **hippocampus** is the brain structure that allows working memory to perform the second of its 2 major functions—the transfer of information into long-term memory. In a general sense, the process that gets information from the external world into our long-term memory is called encoding.

We've seen how information that is deliberately organized and carefully encoded by working memory is easier to recall. Most of our memories do not go through such deliberate encoding, yet they are successfully moved to long-term memory anyway. In this lecture, we'll examine how this is possible and why certain experiences are more memorable—that is, easier to recall—than others.

Generally, people remember the beginnings and ends of things better. Better memory for the beginning is called the **primacy effect**, and better memory for the end is called the **recency effect**. Beginnings are well encoded because they spend the most time in working memory; endings are easier to retrieve because they may still be in working memory at the time of recall.

The evidence for this process comes mostly from dissociations—experimental manipulations that affect one component of the memory but not the other. These experiments may involve reversing the order of items in working memory or changing the speed of item presentation rate, for example. The results indicate that the recency effect occurs in working memory and the primacy effect in long-term memory.

These effects also clarify how rote memorization works: Using working memory to repeat items over and over doesn't promote a strong transfer to long-term memory unless a lot of repetitions are performed. If one thinks deeply about the information instead and elaborates on it in some way, even in a simple way, then the transfer to long-term memory—the encoding—is much stronger. This sort of deep processing can be accomplished without a lot of elaborative rehearsal. Good-versus-bad categorization is one of the easiest ways to encourage deep processing, perhaps the fastest way to enhance memory on the fly.

What other factors affect the likelihood of remembering something we have encoded? Re-creating the context of the original experience—such as revisiting the original location—has been shown to improve recall. Fascinatingly, re-creating the internal context—that is, your mood—can be just as important as re-creating the external context; this phenomenon is called **state-dependent memory**.

Encoding information in a way that leads to strong memory recall takes a lot of cognitive effort. The more you practice deep encoding, the easier it will get, but it will never be perfectly easy or automatic. Sometimes expending even a little cognitive effort can be difficult. Exhaustion, stress, and distractions are among the everyday challenges to successful encoding.

Prospective memory—reminding ourselves to do something in the future—is difficult for most people. It can fail even over extremely short time intervals. The classic "tie a string around your finger" and similar external retrieval cues can be inconvenient, and over long periods they may not even work. The ideal prospective memory cue is one that suddenly appears at the moment we

There are far better ways to aid prospective memory than the traditional string on the finger.

need to remember the instructions. For example, if you need to remember to bring a certain book to work, try associating that book with the image of your front door and the sound of your jangling house keys. ■

Important Terms

hippocampus: A region of the midbrain that allows the transfer of working memory into permanent storage and may coordinate the simultaneous activation of various memory systems.

primacy effect: Better encoding and recall of the beginning of a list or series of events.

prospective memory: Giving oneself instructions to remember or do something in the future.

recency effect: Better recall of the most recently encoded information.

state-dependent memory: A memory whose recall is improved by re-creating the emotional context in which it was learned.

Suggested Reading

Benjamin, *Secrets of Mental Math*.

Mason and Smith, *The Memory Doctor*.

Parker, Bussey, and Wilding, *The Cognitive Neuroscience of Memory*.

Payne and Conrad, *Intersections in Basic and Applied Memory Research*.

Questions to Consider

1. If you think about the brain in evolutionary terms, does it make sense that it might remember images, and even bizarre images, especially well?

2. Research shows that depressed people tend to think a lot about the negative events that happen in a day, but they don't think much about the good things. Can you see how the resulting memories of the past could actually feed into the depression and make it worse?

3. Recite the alphabet in your mind. You can't help but sing it, can you? This is a good example of how dual coding can aid memory retrieval—the letters become linked sequentially by a melody and by the appropriate use of rhyme. Can you think of other examples? Can you create one yourself?

Exercise

Categorizing in terms of good versus bad may have seemed like a simple point, but it actually represents perhaps the best trade-off between using labor-intensive mnemonic techniques and minimal time and effort. Next time you come into contact with some things, or perhaps even names, you want to remember, think of each one and quickly decide whether you would categorize it as a good thing or a bad thing. Which way you categorize each item isn't critical, but notice how images and associations come to mind naturally, effortlessly, and notice that this does make those items easier to remember.

Episodic and Semantic Long-Term Memory

Lecture 7

Episodic memory and semantic memory are both types of long-term memory, but episodic memory is more context dependent, whereas semantic memory is more independent. Both interact with the conscious self via working memory. Interestingly, good encoding of long-term memory seems to alter the neurological paths in our brains and even change the size of the hippocampus.

Long-term memory systems allow experiences to affect behavior over longer temporal windows. We have already encountered 3 kinds of long-term memory—episodic, semantic, and procedural. Here, we'll take a deeper look into how these systems function.

The true virtuoso of multiple long-term memory system interaction is the licensed London taxi driver, who must know hundreds of detailed routes, landmarks, and points of interest. The cabbies' semantic memory supplies their general knowledge of the city's convoluted streets learned across hundreds or thousands of drives around the city; their episodic memories keep them apprised of countless current events, like road closures or traffic accidents, that affect their performance; and their procedural memory controls the muscle movements used in driving.

The relationship between working memory and long-term memory can be described like a library: The stacks are like long-term memory; books (information) are placed there and left alone until needed. The patron desks are like working memory; books are taken from the stacks and brought there, accessed, analyzed, and combined to create some new product. That new product might even be stored in the "stacks" if it's important enough to become a new "book."

Although these 2 forms of memory interact all the time, they are distinct. Long-term memory is mostly about static storage. Working memory is about results. One could argue that consciousness is the experience of what is occurring in working memory.

The defining trait of an episodic memory is that the information is recalled with contextual details. In a way, episodic memory is autobiographical, although we can also have episodic memories where we are not the "star" of the show, like the taxi driver hearing about some 1-day event. If the taxi driver combines several episodes to form a new piece of general knowledge, that will become part of his semantic memory. Episodes where we are not the star may be the most natural contributors to semantic memory.

Working memory allows us to create virtual worlds within our minds. For example, when we read a novel, we visualize its characters. We use this reality simulator for things other than memory: We can speculate about events taking place elsewhere or events in the future; we use it to daydream and to make plans.

Semantic memory is generally much less personal; it is information about the world at large. When we attempt to retrieve it, it arrives in our working memory without context. Semantic memory recall is likely to improve

Memorizing the complicated geography of London's streets has been shown to change the brain structure of London's taxi drivers.

through use of mnemonic tricks. But everything in our semantic memory also got there through episodes of contact with that knowledge. Thus, in some cases, a given memory experience includes aspects of both semantic and episodic memory.

Working memory allows us to create virtual worlds within our minds.

In 1948, psychologist Donald Hebb suggested that the human brain has **neural plasticity**—it undergoes changes, namely enhanced connectivity, as a result of new experiences. In 1973, physiologists Tim Bliss and Terje Lømo induced this enhanced connectivity in the rabbit hippocampus and called the phenomenon **long-term potentiation**. Research has shown that London cab drivers have enlarged hippocampi, adding to the evidence for neural plasticity. Long-term potentiation is now viewed as the primary neural basis of learning. ■

Important Terms

long-term potentiation: Enhanced connectivity between brain regions as a result of new experiences.

neural plasticity: The idea that the brain undergoes physical changes, specifically enhanced connections between brain regions, as a result of learning.

Suggested Reading

Baddeley, Eysenck, and Anderson, *Memory*.

Dere et al., *Handbook of Episodic Memory*.

Tulving, *Elements of Episodic Memory*.

Questions to Consider

1. If someone had damage to working memory, might that person still show an intact semantic memory or episodic memory? Which would most likely be impaired?

2. If you have recently exposed yourself to some sort of learning activity, consider some facts you have learned about that activity, including facts you have learned recently and others that you learned some time ago. Are the recent facts more likely to produce episodic memories of the actual learning experience?

Exercise

Imagine someplace that is relatively close to your house, say within a few miles. Using just your spatial memory, draw a map from that place to your house, including as many details about side roads and interesting locations as you can. Then go online for a map to see the actual layout of the area you mapped. How accurate was your map? Did you draw some streets straighter than they actually are? This is called a regularization error and, as we discuss later in the course, this is one of the sorts of errors our memory systems often commit.

The Secret Passage—Implicit Memory

Lecture 8

Implicit memory is a system that allows humans to learn the structures and patterns underlying many aspects of daily life, from grammar to music to etiquette. Through encoding these structures, it also allows us to make predictions about events in the near future and to draw attention to events that do not fit these patterns so we can act on them if necessary.

The **implicit memory** system contains memories encoded by repeated experience within some context but without any explicit attempt to learn. It is sometimes called the secret passage to long-term memory. The implicit memory system plays a major role in shaping appropriate human behavior.

The kinds of information we can encode in an unintentional manner are different from the kinds we can learn using intentional strategies. Intentional learning strategies are best for remembering specific content and information. The things we can learn unintentionally relate to the structure that underlies that information.

Grammar is one common example of an implicitly learned structure. We learn how to properly form a sentence in our native language years before we ever set foot in a grammar class. Perhaps we couldn't explain these rules, but we could use them. We learn how to speak by hearing speech but also by talking and getting feedback—sometimes explicit, sometimes subtle. Processing that feedback requires tiny bursts of conscious effort.

Psychologists study implicit memory by creating artificial grammars and testing how people learn them. In a typical experiment, subjects are shown "legal" strings of symbols over and over without being told what makes the strings legal. Afterward, subjects are able to distinguish legal strings from illegal ones about 70–80 percent of the time. In follow-up experiments, participants are explicitly taught the grammar before they see the strings. Afterward, they are reliably worse at distinguishing between legal and

illegal strings, as if conscious knowledge of the structure made it harder to use implicit memory.

Implicit memory also allows us to recognize distinct musical genres. Even if you've never heard a certain tune before, you can often pin down its genre from just a few bars because you have been exposed to genre structures so many times.

Implicit memory doesn't capture the specific content within a structure. That's why implicit memory and **declarative memory** work together in complementary and often powerful ways. For example, doctors in training deeply encode symptoms and diagnoses, but they see specific and individual cases of these same issues during their internships, building implicit memory and allowing them to make more confident diagnoses.

After experiencing a pattern over and over, our implicit memories help us interact in reasonable and expected ways.

Script theory is the notion that we learn social behavior through this sort of implicit memory as well. Interpersonal interactions tend to unfold according to a regular pattern. After experiencing a pattern over and over, our implicit memories help us interact in reasonable and expected ways in similar situations. We learn the script.

A script not only tells us what we should be doing now; it also gives us a sense of how events will unfold in the near future. Implicit memory also helps you notice unexpected events that may warrant deeper consideration; it informs which events in an environment will attract your attention.

No matter what you do, or how you live, others will eventually develop a mental script of you specifically and of any category—parent, employee, teacher, stranger, and so forth—to which you belong. Fitting others' scripts will make you seem competent, but occasionally violating scripts will attract more attention and can make you even more effective.

You can learn the world's regularities in a more explicit manner. If you need your knowledge to be declarative—if, say, you are teaching grammar or music—declarative memory will help you communicate your knowledge to others. But if you are only concerned with your own behavior, implicit memory frees up your cognitive resources to focus on specific information, rather than its underlying structure. ■

Important Terms

declarative memory: Memory systems used deliberately to produce a clear, conscious answer to some query; these systems include episodic and semantic memory.

implicit memory: Memories encoded by repeated experience within some context but without a deliberate attempt at encoding; contrast with **rote memorization**.

script theory: The idea that social theory is learned via implicit memory.

Suggested Reading

Graf and Masson, *Implicit Memory*.

Lewandowsky, Dunn, and Kirsner, *Implicit Memory*.

Marsick and Watkins, *Informal and Incidental Learning in the Workplace.*

Reder, *Implicit Memory and Metacognition.*

Questions to Consider

1. Jim is learning to sing. In the hope that it will help, when he's not singing he plays background music that consists of other singers singing scales. Do you think this might actually help him? Why or why not?

2. Jim decides he'd also like to learn the principles of chemistry this way, so he plays lectures about chemistry in the background as he works. Will this help? Why or why not?

Exercise

Think back to some recent event you have experienced and try to separate that event into content (things that happened) versus the structure underlying those happenings. For example, perhaps you are going to a movie, which requires you to go through a certain process both before and after the movie. Even the movie itself may tend to unfold in certain structured ways. Try to notice these background structures, which are the aspect of events we usually encode implicitly.

From Procedural Memory to Habit

Lecture 9

Procedural memory, like implicit memory, is usually accessed without conscious thought. Even if a physical procedure is first explained by a teacher, it is only through practicing it that it truly enters procedural memory, and educators are trying new teaching strategies to take advantage of that fact. Particularly powerful procedural memories form the basis of habitual behavior.

When you begin learning a motor procedure, you rely heavily on your working memory to guide you through the necessary actions. While working memory is powerful, it isn't very graceful. By going through the procedure over and over, what begins as a graceless routine slowly transforms into a graceful orchestra of motor movements.

A well-encoded procedural memory can become so habitual that it is performed entirely without conscious intervention. Many of us, for example,

A complicated task like driving becomes smooth and nearly effortless with practice, thanks to procedural memory.

can drive without thinking about what we're doing. But no matter the skill, it's likely some teacher or book got you started by explaining the behaviors you need to perform, imposing some sort of structure on the learning process. You might have come to understand the structure quite well that way, but understanding and performing are different things. Smooth performance only comes from practice.

The environment simply triggers the procedure, even when it is inappropriate for the context.

Constructivist learning is the notion that a student better understands some structure when he or she must figure it out, rather than having it explained. Explicit instruction can be helpful in situations where there is a single right way do something. However, it can stifle creativity in situations where there are multiple ways to effectively combine processes. The principles of procedural memory hold just as true for cognitive processes, such as those underlying critical thinking, creativity, and effective composition—as physical processes.

Research from my own lab supports both the contentions of constructivist learning. Using an Internet-based software system called peerScholar, my colleagues and I have shown that when students are given repeated experience evaluating the work of their peers, they become better evaluators overall, and their ability to detect the quality of their own work is also enhanced.

Colloquially, we often refer to well-formed procedural memories as **habits**. Habits occur when you have practiced some procedure so much that you are no longer in control of it. The environment simply triggers the procedure, even when it is inappropriate for the context. In this sense, reading can be viewed as a habit, as demonstrated by the Stroop task. A person is asked to look at a list of color words printed in color ink, but the word and the color never match; for example, the word "red" is printed in blue ink. The person is asked go down the list and say the color of the ink; however, most people find this nearly impossible. Reading the word itself is such a strong habit, we cannot break it even when we want to.

By now, you should be seeing a clear distinction between memory systems used in a deliberate way to produce a clear, conscious answer to some query—that is, declarative memory—and memory systems used automatically, with little or no conscious mediation. These systems are called **nondeclarative memory**, and they include both procedural and implicit memory.

Recall that implicit memory encodes regularities in the environment and captures the underlying structure of things, which can then be used to guide behavior in the present. Procedural memory can do this too; the most famous examples of this are Pavlov's dogs, whose bodies went through the procedure of salivating when they heard a bell ring, even if the food that usually accompanied the bell was not present.

Through this process, which Pavlov called **classical conditioning**, we can subconsciously learn that certain stimuli predict certain other stimuli. As long as the predictable link between the stimuli is maintained, we will respond to the first stimulus as if the second were coming, even when we don't want to, even if we are aware that it isn't. Once created, habits are hard things to break. ■

Important Terms

constructivist learning: The principle that it is easier to learn structure through direct experience of the structure rather than by explanation.

classical conditioning: The encoding of procedural memory via the implicit memory system.

habit: A form of procedural memory that is so well formed the actor is no longer in control of whether or not he or she performs it.

nondeclarative memory: Memory systems used with little or no conscious mediation, such as procedural and implicit memory.

Suggested Reading

Covey, *The 7 Habits of Highly Effective People*.

Herbert, *On Second Thought*.

Tulving and Craik, *The Oxford Handbook of Memory*.

Questions to Consider

1. Imagine you are about to take a new job and you decide to use this as an opportunity to quit 2 habits: smoking and using a handheld device while driving. Which habit to you think might be harder to break and why?

2. Can a procedural memory form without our intention to form it? In the lecture I mentioned examples where a procedure was initially guided by working memory, but then control was eventually lost as the procedure became more automatic. But imagine the following: Out of sheer laziness, a person might toss dirty clothes on furniture or pile mail on a table. If this happens every day, it becomes a habit, one that can be hard to break. So does this imply that any motor behavior repeated often enough, for whatever reason, becomes automatized?

Exercise

Next time you are sitting at a table, put both hands on the table and tap the table with your left and right index fingers as follows: left, left (pause) right, right (pause) left, right, left, right, left, right (pause) right. Do this over and over, and try to go faster and faster without making mistakes. Through repetition, this simple procedural memory should get more accurate and faster. What you are experiencing are the rudiments of rhythm and how they become automatic with repetition. Virtually every musician must ultimately learn these rudiments to perform well, whether to explicitly provide rhythm as a drummer would or to attach melodies on top of a rhythm as a singer or other musician does.

When Memory Systems Battle—Habits vs. Goals

Lecture 10

Breaking a bad habit or forming a good one involves a battle between our declarative and nondeclarative memory systems. Habits develop because the behavior is rewarding in some way, and they are reinforced by contextual clues that may not be under our control. The best way to break a bad habit is to replace it with a positive one, but this can be much harder than it sounds.

To defeat a bad habit, we have to remember our resolution to break it, which means loading an episodic memory into working memory whenever we are within the context where that habit might take control. Our declarative systems must take charge at the right time, or else the nondeclarative system will take control as usual. When declarative systems win this battle, we praise our own willpower; when nondeclarative systems win, we say willpower has failed. But memory is a more fruitful way to think about this age-old battle.

Battles between declarative and nondeclarative memory systems are a common aspect of our daily lives. The brain regions called **basal ganglia**, which are responsible for habits, require far less energy than the prefrontal cortex where goals are created and managed, and habits free the cortex up for complicated or unfamiliar tasks.

Nondeclarative systems exert control when all seems normal, and declarative systems step in when things are unusual. A **capture error** occurs when the declarative system seems to be working fine but still has difficulty taking control back from our habits. Capture errors can have dire results when they occur in contexts were errors are costly.

Capture errors are related to problems of prospective memory. When, for example, we try to add bringing a book to a friend to our usual morning ritual, we are breaking a habit. We have even more trouble avoiding capture errors when we must both remember to cue the goal at the right time and use that goal to take control of behavior.

When we want to take control of habit on a permanent basis or eliminate it entirely, the challenge is even greater. The original habit likely formed because there was something about it we found rewarding. Plus, throughout the development of our habit, our brains formed new connections among stimuli and between brain regions. Thus, our brains might be influencing us to complete the habitual behavior.

Stimuli related to habits are almost by definition regularly present in our life. For example, if you are trying to break the habit of computer gambling, just turning on the computer to do other work could stimulate you to visit a gambling site.

The original habit likely formed because there was something about it we found rewarding.

When we wish to permanently change a habit, we need to keep our goal of breaking the habit present in working memory every time we might engage in the unwanted behavior. We are virtually doomed to fail. When we do, the reward that helped form the habit originally will still be present, and each failure will strengthen the habit further.

Besides taking extraordinary steps to block stimuli for the old habit, it is sometimes useful to use working memory to support a new habit that competes with the current habit. To be effective, you must stick with the new habit for a long period of time; the folk belief that 2 weeks is enough time to form a habit is, unfortunately, an underestimate. Studies indicate you might need anywhere from 3 to 36 weeks to form the new habit, with 9 weeks being average.

When you form a new habit, at the brain level you are forming and shaping new connections. The hope is that with enough consistency, you can make these new connections stronger than the old ones. The best time to try to change a habit is in the context of more general change.

Evidence suggests the existence of a continuum from weak memories to stronger memories all the way to habits. Therefore, it is best not to start bad

habits in the first place, but if you have to have a bad habit, then the best bad habit is a weak bad habit. ■

Important Terms

basal ganglia: A group of brain regions associated with motor control, both voluntary and involuntary.

capture error: A situation in which we are consciously trying to not perform a strong procedural memory (i.e., a habit) but are unable to stop.

Suggested Reading

Eichenbaum and Cohen, *From Conditioning to Conscious Recollection*.

Forgas, Williams, and Laham, *Social Motivation*.

Vanderwolf, *The Evolving Brain*.

Questions to Consider

1. Why do we sometimes put our milk in the microwave when we mean to put it in the fridge? From what you know now, could you devise a potential explanation?

2. Brain injury often has its biggest effects on declarative memory systems. How do you think this tends to affect the behavior of the injured patients? Do you think they would have a harder or easier time escaping habitual behaviors?

Exercise

Pick some very regular habit and try to avoid it for a day, or even for a few hours. When do you most feel it trying to control your behavior? Is it when you are around cues associated with that habit? For example, if you tend to chew your nails, do you tend to do so in a specific context? How much conscious control (i.e., working memory) does it take to avoid the behavior? Would this activity be harder if you were tired?

Sleep and the Consolidation of Memories

Lecture 11

Encoding is important to getting information into memory, but it is not the whole story. Sleep seems to play a role in consolidating the memories we encode during the day, and different stages of sleep consolidate different kinds of memory. Slow-wave sleep seems critical to the consolidation of declarative memories, and rapid eye movement sleep is critical to the consolidation of nondeclarative memories.

Perhaps the most basic debate with respect to sleep is whether it serves any sort of critical function at all. Experimental evidence now suggests that sleep plays a role in reinforcing and reorganizing our memory systems to make the memories of recent events stronger, a process termed consolidation.

It has been suggested that sleep's only purpose is to conserve energy during the hours of darkness, when human senses are inadequate for hunting and gathering. But experiments have shown that sleep is critical for survival; extreme sleep deprivation may even be fatal.

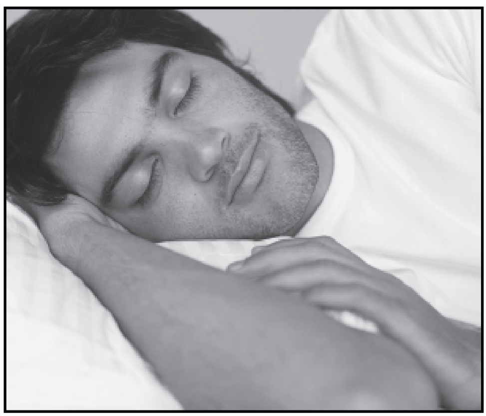
There are 5 stages of sleep, each of which may be relevant to the consolidation of different sorts of memory. Scientists distinguish between types of sleep by the different patterns of electrical activity each produces in the brain. In general, the sleep stages can be divided into **rapid eye movement (REM) sleep** and non-REM sleep. We cycle through the stages several times during the night.

The deepest stage of non-REM sleep is stage 3, called **slow-wave sleep**. During stage 3, our brains receive very little input from our external environment. If you are awakened during stage 3, you would feel extremely tired and sluggish. One function of slow-wave sleep may be the repair and maintenance of our bodies. REM sleep is the stage of sleep when we dream. During REM sleep, our glands stop releasing several neurochemicals that send signals to our motor neurons. This produces a paralysis called **REM atonia** that keeps us from acting out our

dreams. Early in our night's sleep, we tend to spend most of our time in slow-wave sleep. As the cycles repeat, we reduce the time in slow-wave sleep and increase the time in REM sleep.

When we dream, the electrical activity of our brain looks extremely similar to how it looks when we are awake and alert. We think, solve problems, and do all sorts of real-world things in REM sleep, but the stimuli come from inside our brains and not from the external world. Evidence suggests dreams are replays of critical events from our recent past, making our memory of those events more stable. In shock-avoidance tests performed on rats, it was found that rats being trained to avoid shocks (that is, those forming nondeclarative memories) spent 25 percent more time in REM sleep than did control (unshocked) rats. This suggests that dreaming allows us to consolidate new motor behaviors without physical practice.

In contrast, slow-wave sleep seems to improve declarative memory consolidation. Among human test participants, humans who spent more time in slow-wave sleep were much better at memorizing lists than those spending more time in REM sleep. The hippocampus, which we know is critical for the transition of memories from working memory to episodic memory, is very active during slow-wave sleep. Some researchers speculate that the hippocampus is a conductor of sorts: It connects activity in different brain regions to form a meaningful overall pattern, then brings back that pattern by stimulating brain areas to fire the way they did when the episode occurred. Maybe it is performing these sorts of functions as we sleep as well.



Scientists have long debated the purpose of sleep, but evidence now suggests it plays an important role in the consolidation of memory.

Working memory seems to be online during REM sleep, which is why we

are conscious of our dreams. Working memory is not online during slow-wave sleep.

Infants have been shown to spend 50 percent or more of their sleep in a REM state, whereas time spent in REM sleep declines as we age and in some older adults may be missing altogether. Slow-wave sleep also declines as we age. This suggests that memory consolidation in general may be less important as we age, when we are not trying to learn as many new skills. ■

Important Terms

rapid eye movement (REM) sleep: The sleep state during which dreaming occurs.

REM atonia: The temporary state of paralysis that occurs during REM sleep that prevents us from acting out our dreams.

slow-wave sleep: The deepest stage of sleep, in which memory consolidation occurs.

Suggested Reading

Medina, *Brain Rules*.

Plihal, *Differential Effects of Early and Late Nocturnal Sleep*.

Weingartner and Parker, *Memory Consolidation*.

Questions to Consider

1. Often when people suffer concussions, they are never able to remember the events that occurred just prior to their injury. What does this suggest about the link between head trauma and processes of consolidation?

2. Some people claim they never dream. This is likely untrue, but some people dream much less than average. What sort of learning tasks would you expect these people to have trouble with?

Exercise

The next time you wake up and can remember a dream you were having, think about the activities you were performing in that dream. Are they at all similar to activities you have been recently performing in life? We know that memories are strengthened with practice, and the lecture discussed a link with procedural memory, but the data suggests that dreaming does not strengthen episodic memories. Does this mean that we never dream about an episode we remember? Think about your own dreams and see whether they ever include entire episodes from conscious memory—that is, not Edgar Allen Poe's "dream within a dream," and not fragments from your day, but intact instances of episodic memory within a dream.

Infant and Early Childhood Memory

Lecture 12

Babies spend much of their time learning the regularities of their environment and developing procedural memories. Between the ages of 2 and 5, the brain structures underlying working memory and episodic memory slowly mature. By about 5 years old, all memory systems are online and functioning. The memories we form thereafter can be retained long-term, and we begin piecing those memories together to create an ongoing sense of self.

Most people have no memories before the age of 3. Our inability to remember events from before that age is so pervasive that it's called **childhood amnesia**. But this amnesia only refers to episodic memory; not all memory systems take this long to develop.

At birth, our brains contain most or all of the brain cells we will ever have, about 100 billion. What's missing is connectivity. As babies interact with the world, connections form between neurons. This neural plasticity allows the brain to wire itself based on early sensory and motor experiences. Infant brains form connections more quickly, and may also form more connections overall, when exposed to lots of variable stimulation.

Developing the light reflex—pupil constriction when exposed to light—is the first step in developing iconic memory, whereas hearing, and possibly echoic memory, seems to be present before birth. Most other behaviors are acquired gradually as brain connections develop.

By about 3 days of age, babies can mimic facial expressions; this is called **modeling**, and it is evidence that a baby's procedural memory system is functioning and growing. By 3 months, most babies have learned that their behaviors can affect their environment—for example, shaking a rattle to make a noise. The baby is forming simple semantic memories. At 5 months, many babies begin acting uncomfortable around strangers. What begins as attraction to the familiar develops into an avoidance of the unfamiliar. This

suggests the development of links between perceptions of familiarity and emotional systems.

Babies begin to babble at 5 months, begin imitating vocal units at 8 months, and begin mimicking animal sounds by 1 year. The sounds they make are derived from their environments, an indication that their implicit memory systems are functioning well.

Experiments show that babies remember for longer periods of time the older they get. The increasing memory skills correspond to behavioral leaps and bounds over the first 2 years of life, particularly the acquisition of language.

Before the age of 2, a baby's implicit learning and procedural memory development reign supreme; infants also get a lot more REM sleep than children and adults, supporting the suggestion that dreams consolidate procedural memories. On the other hand, most of us do not form episodic memories before the age of 2. The hippocampus and the prefrontal cortex are slow to develop, neither reaching maturity until 3 or 4 years of age.

Babies don't form episodic memories of their first steps, but they don't need to. Thus their brains are wired for forming procedural memories.

Between the ages of 2 and 5 years old, children display a powerful ability to learn the regularities of language, which may reflect implicit memory, but once language is learned, it allows us to learn things in a way that can lead to semantic and episodic memories.

As early as 18 months of age, most children have learned their own name; at this same time, the first

struggles for independence also emerge. At about 3 years of age, children can describe their dreams; this is important because dreams share certain tendencies with autobiographical memory. The year between 3 and 4 years old might be especially important for the development of a sense of self. In this period, behaviors like cooperation, self-consciousness, and negotiation appear. By the age of 5, children are not only able to play games that involve rules, they can and do cheat—evidence of a strong working memory.

Once all memory systems are in place at around the age of 5, the clouds of childhood amnesia dissipate for good. However, during periods of intense brain development, there is also evidence of **synaptic pruning**, the removal of weak brain connections to make space for more new connections. This happens during infant development, but it also occurs during adolescence. ■

Important Terms

childhood amnesia: The human inability to encode episodic memories before about the age of 3.

modeling: Learning by imitation; specifically, an infant's mimicry of others' facial expressions.

synaptic pruning: The removal of weak brain cell connections to make way for new ones that occurs at least twice in normal, healthy humans: once in infancy and once in adolescence.

Suggested Reading

Bauer, *Varieties of Early Experience*.

Markowitsch and Welzer, *The Development of Autobiographical Memory*.

Nelson, *Memory and Affect in Development*.

Questions to Consider

1. What is your earliest childhood memory? Are you sure what you remember is the event itself, or could it be based on later retellings of the event? How would you know for sure? How might a study of the memory of adopted children be interesting? After all, adopted children are unlikely to hear stories about their life prior to adoption. What might you expect such research to show?

2. At various points in the course, I have made dramatic claims about how important memory is with respect to functioning smoothly in our lives. Perhaps this claim seems especially valid as we consider the ways that our various memory systems support the development of a growing child. Can you imagine how this development process would be different if the child's implicit memory system were less efficient than normal? What if it took 2 years for implicit memory to be fully functional? What implications would that have for the child and caregiver?

Exercise

Ask yourself and a few of your friends the following questions: Do you know how old you were when you first walked? Do you know how old you were at the time of your first retrievable episodic memory? Do you see any relationship and, if so, why might that be?

Animal Cognition and Memory

Lecture 13

The available evidence suggests (but does not prove) that apes, elephants, birds, and even octopuses possess all of the same memory systems as humans and therefore may possess a sense of self. The specifics of how these systems function, however, could be quite different. Researchers face 2 challenges: how to test animal memory without the help of language and the ethical implications of self-awareness in animals.

They say an elephant never forgets, and chimps have proven themselves surprisingly adept at simple memory games—often more adept than humans. These studies are not only interesting but also raise questions about what is and is not uniquely human.

Our memory is critical to our sense of self; imagine not remembering anything that had happened in your life prior to this moment. Our memories give us a sense of a continuing self that exists across time and space. A catastrophic loss of memory results in a catastrophic loss of self, as seen in advanced cases of Alzheimer's disease.

While some animals possess something like language, none use it the rich way humans do. They would not have anything like the phonological loop but may have something like the visual-spatial scratchpad, or even a type of working memory based on smell instead.

Researcher Gordon Gallup tested for self-awareness in animals using mirrors. When confronted with a mirror, most animal species were initially afraid of this "other" animal. Some became **habituated** to the image once they realize it is not a threat. Some animals, including chimpanzees, used the mirror to inspect themselves. When subjected to a rouge test—having their faces marked with rouge without their knowledge—chimps react much like human babies do, curiously poking and prodding the colored spot. This implies awareness that the self has changed and, by extension, that chimps have a sense of self.

Gallup's experiments have suggested an ever-growing list of animals that pass the rouge test: nearly all of the great apes; dolphins and killer whales; elephants; and some bird species. Animals clearly have procedural memory (e.g., you can train a dog to fetch) and something like semantic memory (e.g., your cat knows that the sound of the can opener means food). The memory systems in doubt are working memory and episodic memory.

A wide range of demonstrations have implied that animals do have episodic memory. "What-where-when" memory has been demonstrated for a number of bird species and in lab rats as well. Scrub jays appear to be able to worry and anticipate future events, just the sort of planning humans use their working memory for. Furthermore, lab rats with damaged hippocampi seem unable to form episodic memories, just like humans.

Perhaps most startling of all, planning and deception—the hallmark of cognitive development in human children—have been discovered in an octopus housed at the Seaquarium in Miami, Florida. It not only waited until its room was dark and quiet to sneak out of its tank and steal lobsters

Elephants seem to have excellent memories, particularly a herd matriarch, who seems to serve as a repository for generational memory.

from another tank nearby, it actually hid the shells, as if trying to cover up its crime.

The cliché about elephants is true; they have especially impressive memories. The matriarch of an elephant clan must lead her clan to good water sources year after year, season after season. What is more, elephant matriarchs are able to adapt this process to different weather patterns. The brains of elephants are actually more densely packed with neurons than human brains and have more folding, so they can store more information.

What are the larger implications of this evidence? First of all, if animals have a sense of self, they are more like us than we have previously believed, and this may have broad ethical implications for their use and treatment by humans. Scientifically, the fact that the same sorts of memory systems operate within so many different species points to the importance of these systems for survival. ■

Important Term

habituation: An acquired tolerance for a stimulus in an environment.

Suggested Reading

Hiby and Weintraub, *Conversations with Animals*.

Kendrick, Rilling, and Denny, *Theories of Animal Memory*.

Spear and Miller, *Information Processing in Animals*.

Questions to Consider

1. If you have or know someone with a dog, does the dog seem to hold a grudge if it is, say, left alone for a while? The dog might not be pleased at the time, but does it hold a grudge when the family returns? If not, do you think that means dogs forgive because they so easily forget?

2. The elephant with the best memory is the matriarch of the herd. Unfortunately, this matriarch also tends to have the best tusks. As a result, ivory poachers often go after the matriarch. If you think of this at the herd level, what are the consequences for the long-term memory of the herd? In what ways do human families experience analogous losses?

Exercise

If you have a nonhuman animal of any sort in your home, place a mirror in front of it and see how it reacts to the reflection. Based on its reaction, try to understand what sorts of memory processes might be occurring. If you have contact with young children, especially those younger than 3 or 4 years old, try the same thing. How are the reactions different? How easy or hard is it to make inferences about memory based on these reactions?

Mapping Memory in the Brain

Lecture 14

Thanks to functional magnetic resonance imaging, neuroscientists are creating a map of the brain showing which areas are responsible for which functions. It seems that we use the same brain regions to recall a memory as we used during the original experience; for example, the phonological loop occurs in our language center. The more we learn about brain function, the more support we find for cognitive psychology's theories of memory.

The human brain weighs only 3 pounds but contains about 100 billion neurons, about the same as the number of stars in our galaxy. Although it accounts for only 2 percent of body weight, it consumes about 20 percent of the body's energy. Obviously, it is doing a lot of work.

The branch of psychology concerning the link between cognitive processes and the brain is called cognitive neuroscience. Over the past 10 to 20 years, we have gained some powerful tools allowing us to study these links. The most powerful of these tools is **functional magnetic resonance imaging (fMRI)**.

fMRI is a method for watching blood flow through an active brain. A regular MRI is a common procedure for body imaging; it works much like an X-ray but can show distinctions between different tissue densities, not just between soft tissue and bone, and produces a 3-dimensional image instead of a flat one.

The "functional" in fMRI means that the patient performs some function during the scan. Brain tissue works much like muscle tissue; when an area of the brain is active, blood flow to that area increases. So an fMRI detects where the blood is going as people perform various tasks. Neuroscientists and psychologists have used such fMRI images to create a map of the brain.

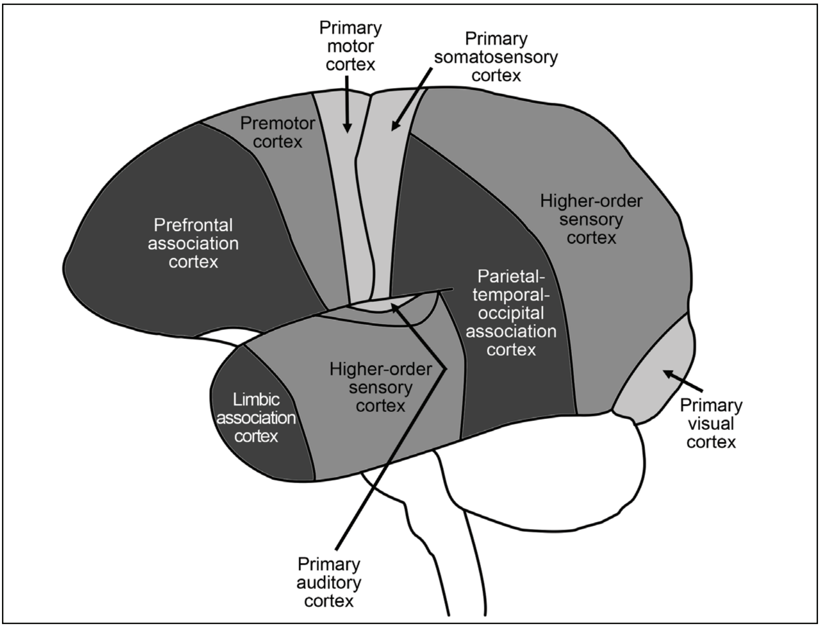
The brain can be subdivided into 5 regions: the primitive midbrain and the 4 lobes of the **cortex**.

- The occipital lobe, at the back of the head, is home to the primary visual cortex, the part likely associated with iconic memory.

- The temporal lobe, just above each ear, is where the primary auditory cortex resides; this is the part likely associated with echoic memory.

- The very top of the brain is the **parietal lobe**, and it is especially active when we are processing input from our bodies or spatial information.

- The front of the brain, or **frontal lobe**, is activated during decision making and intentional action.



The primary sensory and motor cortex (light areas), higher-order sensory and motor cortex (gray areas), and the 3 association areas of the cortex (dark areas) are co-activated during complex memory retrieval.

The phonological loop, part of our working memory, allows subvocal articulation (talking to ourselves) and subvocal reception (replaying others' speech). fMRI studies reveal that these processes occur in **Broca's area** and **Wernicke**'s **area**, the exact same areas used to produce and understand speech. Another part of working memory, the visual-spatial scratchpad, produces a lot of blood flow in the occipital cortex, which is also used to process visual stimuli.

Brain tissue works much like muscle tissue; when an area of the brain is active, blood flow to that area increases.

Using working memory to solve problems involves a more complex process. Scans of people involved in deep encoding show activity in a subarea of the frontal lobes called the **dorsolateral prefrontal cortex** and in the hippocampus, as well as activity in the areas corresponding to what the person is trying to remember. Current theory suggests that the frontal lobes are activating the other regions but that the hippocampus creates the episodic memory by binding the regions together.

Retrieving episodic memory involves a similar process. For example, if someone asks you where you went on vacation last year, Wernicke's area receives the question and activates the working memory in the dorsolateral prefrontal cortex, which activates the hippocampus. It is not clear whether the hippocampus is activated to retrieve the information, to re-encode it after retrieval, or both. Finally, the areas where the relevant information is stored are activated.

Retrieving semantic memories doesn't involve the co-activation associated with episodic memory retrieval. Instead, areas called the association cortices in each lobe of your brain are activated. These areas are encoded with abstract concepts rather than specific incidents.

Procedural memory resides in a strip of cortex that runs over the top of your head from ear to ear called the motor cortex. Signals originating in the motor cortex are sent through the cerebellum, which refines the information. So

the motor cortex controls raw movement, and the cerebellum makes that movement graceful.

One of the most encouraging aspects of all these findings is the extent to which the neuroscientific findings match up with findings from cognitive psychology experiments. The theory of memory emerging from both disciplines seems to be on the right track. ■

Important Terms

Broca's area: The brain region involved in speech production.

cortex: The outer mantle of the cerebrum.

dorsolateral prefrontal cortex: The area of the frontal lobe where current theory indicates that working memory resides.

frontal lobe: The lobe at the front of the cortex involved in decision making, impulse control, and long-term planning.

functional magnetic resonance imaging (fMRI): An imaging process that uses magnets to create detailed images of which areas of the brain are active during certain tasks by showing the blood flow to each region.

parietal lobe: The lobe at the top of the cortex that contains areas for processing sensory and spatial information.

Wernicke's area: The brain region involved in language recognition.

Suggested Reading

Eichenbaum, *The Cognitive Neuroscience of Memory*.

Matthews and McQuain, *The Bard on the Brain*.

Schacter, *Searching For Memory*.

Questions to Consider

1. Based on what you now know about the brain and about fMRI, if I was scanning your brain while you were imagining seeing a rainbow, which brain lobe would show the most blood flow? If the rainbow then reminded you of the perfect rainbow you remember seeing on that trip you took to Hawaii with a special someone, which areas of the brain would then show increased blood flow?

2. In the movies, mummies always walk in a very clunky and graceless manner. It seems that one part of their brain, at least, does not survive the resurrection intact. Which parts of a stereotypical mummy's brain seem least intact and why?

Exercise

Do some push-ups, climb some stairs, or do some other exercise, and pay attention to how the muscles feel as you work them. Now spend a while thinking about and speaking aloud all the words you can think of that begin with the letter *r*. You're using Broca's area to do this, an area located just above your left ear. Does that part of your brain start to feel sore, like your muscles did when you worked them out? Probably not. What do you think the difference is? When you work muscles, muscle tissue breaks down; then it is built back up stronger than it was before. But when you use brain tissue, you just use it. Brain parts do not get "bigger and stronger" with work; instead, they strengthen by forming new connections, as was the case for hippocampi of London cabbies. So brain tissue is like muscle tissue in some ways, but not in others.

Incidentally, at one point in history people thought brain tissue was exactly like muscle tissue and thus that you could tell which parts of the brain a person used a lot by feeling the bumps on their heads (apparently caused by pressure from the bulging brain tissue). Thus, instead of having your palm read, you could have your head read. If you'd like to learn more about this misconception, look for the term "phrenology" on the Internet.

Neural Network Models

Lecture 15

Cognitive neuroscientists have created biologically inspired neural networks—computer models of the brain—to tease out the complexities of human brain functions in general and memory in particular. These models indicate that no single neuron is particularly important to cognition; it is the relationships among them that matter.

Neurons, or nerve cells, are covered in branches, through which they send and receive signals from many other neurons. These signals may be excitatory (on) signals or inhibitory (off) signals; when the number of excitatory signals received outweighs the number of inhibitory signals received, the neuron fires—that is, it sends a signal out. The entire complexity of cognition arises as a result of interconnected networks of these very simple signals.

Early psychologists tried to emulate and predict the behavior of the brain through mathematical modeling, but the mathematics became far too complex. Now, biologically inspired **neural network** models attempt to imitate this behavior through the interaction of neuron-like processing elements.

Neural network models, and cognitive models in general, are computer-based models that not only try to simulate the intelligent behavior of humans, they model the physical brain systems underlying that behavior. The basic building blocks of these models are artificial neurons called **nodes**. Real neurons operate by sending electrochemical signals—on and off, positive and negative. Nodes signal via electricity rather than chemicals.

Neural network models contain input nodes that create the signals and output nodes that respond to them. When input nodes are on, we assign them a value of 1, and when they are off, we assign them a value of 0. Each signal the output node receives is then given a weight. The output node sums the number of 1s and 0s it receives from all the input nodes, multiplies them by the weight, and compares the result to a threshold value. If the total weighted

input is greater than the threshold value, the node fires. If less, it does not fire.

The first neural network models hit a snag when trying to model the "exclusive or" function—making an output node fire when just one of the inputs was active but not both. This problem stopped neural network models in their tracks for almost 30 years, until scientists began building larger networks. In a large network, no single node is especially critical; it is the overall pattern of firing that matters. This is called **parallel distributed processing**.

In a large network, no single node is especially critical; it is the overall pattern of firing that matters.

Scientists are reasonably certain that the brain represents concepts in a distributed manner for 2 reasons: First, an fMRI typically shows many different brain areas activated when a person tries to perceive or remember an event or concept. Second, when people suffer brain damage or the brain ages, they do not lose concepts; instead, these people show a pattern of memory loss termed graceful degradation, a general impairment of memory not specific to any one concept.

Via connections between nodes, initial input to a neural network causes changes to the states of other nodes within the network in a feed-forward structure. Virtually all neural network models therefore use parallel processing: Nodes are not considered one at a time; the input to all the nodes in the network is considered simultaneously. The nodes all change their activations—or don't—together. In comparison, the chip in your computer or cell phone likely uses serial processing, making changes to one node at a time.

Neural network models all need to be trained before they work effectively. Input is given to the network; then the difference between the output produced and the output the scientists wanted is determined. The scientists adjust the connection weights accordingly and run the text again, repeating the process until the error is reduced or eliminated. Because these are parallel

distributed networks, a change to one node changes all other nodes, so the training process can be very complex, just like the human learning process.

Models that integrate slow learning systems and fast learning systems re-create the relationship between the association cortex and the hippocampus. Therefore, they can produce output that models our semantic and episodic memory systems, respectively.

All of these models are still just theories for the most part, but we can use them to run tests that advance our understanding of memory systems. ■

Important Terms

neural network: A system of on/off switches interconnected in such a way as to imitate the structure of the brain or a region of the brain.

node: A switch in a neural network that stands in for a neuron.

parallel distributed processing: A form of neural network processing where the overall pattern of ons and offs is more important than the on/off state of any one node.

Suggested Reading

Gurney, *An Introduction to Neural Networks*.

Haykin, *Neural Networks and Learning Machines*.

Konar, *Artificial Intelligence and Soft Computing*.

Questions to Consider

1. Imagine a simple network with 2 input nodes and 1 output node. Can you come up with values for the weights and for the output node's threshold that would allow the network to solve an "or" problem, meaning that the output node should fire any time the first or the second input node is on?

2. Many students are interested in psychology because it seems more human and real than, say, chemistry or physics. These students go on to become professors of psychology. Can you see why this tendency might work against a widespread use of computational approaches to understanding the mind?

Exercise

The next time you are in a room with about a half-dozen friends, bring up some issues that people can either be for or against, then ask people to raise their hands when they are for a given issue. Notice that there are some people who you will often agree with, others who you will often not agree with, and still others that you are as likely to agree with as not. If you imagine the amount of agreement between you and another as a link between you, that link is kind of like the weight between 2 nodes in a neural network; sometimes this link is positive, sometimes negative, and sometimes it is almost zero. When thought of this way, can you see how weights affect the amount of influence one node might have on another?

Learning from Brain Damage and Amnesias

Lecture 16

Damage to specific brain areas related to memory can give rise to very specific functional deficits, deficits that take a real human toll. Studying these patients demonstrates the importance of memory systems to our ability to interact with our world. Studying patients with brain damage has also helped neuropsychologists better understand how the brain executes the various functions related to the different memory systems.

Neuropsychologists are doctors who treat patients who have suffered some form of brain injury. They also study such patients to discover links between the brain and behavior. Patients who have suffered brain damage often show complex behavior patterns; one memory system may be damaged while others are fine.

The famous case of musician and conductor Clive Wearing demonstrates what happens when a person has damage to his frontal lobes and his hippocampus. Clive cannot retrieve any episodes from his life before the damage (a condition called **retrograde amnesia**), and he cannot form any new episodic memories (a condition called **anterograde amnesia**).

Clive hasn't actually lost his episodic memories. From imaging studies, we know that the frontal lobes play an important role in the initiation of action, and retrieving memories is a form of action. We see similar retrieval problems in patients who have undergone frontal lobotomies—the severing of connections between the frontal cortex and the rest of the brain. Less extreme versions of retrograde amnesia are quite common and usually short-lived. A concussion causing swelling of the frontal lobes commonly causes **temporary graded amnesia**, where the person first has no episodic memories, then slowly regains them, starting with those furthest in the past and moving toward the present.

Anterograde amnesia was first linked to hippocampus damage because of an epilepsy patient known as HM. HM volunteered for experimental surgery to remove his hippocampus and amygdale in an attempt to stop

his severe and frequent seizures. The surgery worked, but it also caused anterograde amnesia.

Both Clive and HM retained functioning working memories. You can ask them questions, and they will try to answer, although their memory problems may prevent an accurate response. Their semantic memories are also intact. They still know things about the world, and they can show that knowledge either declaratively or nondeclaratively. Both Clive and HM also retained their procedural memories, but the interesting thing is that HM and other patients with anterograde amnesia can learn new procedures.

The interesting thing is that … patients with anterograde amnesia can learn new procedures.

Another form of memory loss related to brain damage is **agnosia**, meaning "lack of knowledge." Those who suffer from it show a disconnect between their ability to see and hear versus their ability to understand what they are seeing and hearing. So a person with agnosia might see a glove on a table and not understand what it is but can identify it when seeing someone put it on. This is semantic memory—knowledge of the world and the things within it.

Agnosias demonstrate how once memories are created and stored, we use them to interpret what we see, feel, hear, taste, or smell. People with agnosia tend to have damage to cortical areas surrounding the primary cortex of the affected sense. There is an especially interesting form of agnosia called **prosapagnosia**, the inability to recognize human faces. Prosapagnosia occurs when the fusiform gyrus is damaged. We now believe this area is critical for forming holistic perceptions—that is, perceptions based on how collections of features occur together.

Neuropsychological cases can be especially interesting when one finds 2 syndromes that are essentially opposites of one another. Patients who suffer from **Capgras delusions** can recognize objects or people just fine, but the things they recognize do not feel familiar to them. They may report that their spouse has been replaced with a duplicate, for example. Since familiarity

arises from implicit learning, this disorder reflects failure of nondeclarative memory in a context where declarative memory is working fine.

Tourette's syndrome is a disorder of procedural memory, ranging from the well-publicized blurting of obscenities to simple tics. Patients with Tourette's are slower to acquire procedural memories. By comparison, patients with HIV/AIDS may show a decreased ability to execute procedural behaviors. Both conditions negatively affect a brain area called the **striatum**. In contrast, patients with obsessive-compulsive disorder have enlarged striata. ■

Important Terms

agnosia: The failure to comprehend the meaning or function of things otherwise correctly and accurately perceived.

anterograde amnesia: The inability to form new memories after a triggering neurological event.

Capgras delusions: A failure of memory that allows a person to recognize objects or people they have encountered before, but recognition is accompanied by a strong sensation that those objects or people are unfamiliar.

prosopagnosia: The inability to recognize faces, despite being able to recognize other objects without difficulty, caused by damage to the fusiform gyrus.

retrograde amnesia: The loss of memories from before a triggering neurological event.

striatum: A brain region associated with procedural memory.

temporary graded amnesia: The temporary loss of memory of events leading up to the triggering neurological event; the victim's older memories return before the more recent ones, and events immediately before the event may never return (e.g., a concussion patient may never remember being hit on the head).

Suggested Reading

Baddeley, Kopelman, and Wilson, *The Handbook of Memory Disorders*.

Cermack, *Human Memory and Amnesia*.

Emilien et al., *Memory*.

Questions to Consider

1. The current approach to dealing with extreme aggressive behavior is to tranquilize the patient with drugs. In what ways is this actually a worse solution than, say, a frontal lobotomy?

2. Would you rather have retrograde amnesia or anterograde amnesia? Why?

Exercise

Sometime when you are out, pretend (if only to yourself) that you have no memory of your past at all. How many of your interactions would be different? Pick a time of day—say, 2 pm—and think what it would be like if anything that happened after that time was lost completely. What would you have lost over, say, a 3-hour period?

The Many Challenges of Alzheimer's Disease
Lecture 17

Alzheimer's disease is the greatest thief of memory we have ever known in terms of how much it steals and how many it steals from—both patients and their caregivers. Much is understood about the progression of the disease, but little is known about its causes or cure. That said, there are many lifestyle interventions that may slow or prevent disease onset, and researchers are developing technologies to improve quality of life for both patient and caregiver.

Alzheimer's disease is predicted to strike 1 in 85 people globally by the year 2050, and for each patient, there will be another 1 to 3 caregivers whose lives may change almost as dramatically as the patient's. Alzheimer's disease is an entirely different process from age-related dementia. We may lose some memory function as we age,

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Although there is no cure for Alzheimer's disease, there are many interventions that can improve quality of life for patients and their loved ones.

but nothing nearly as dramatic and progressive as that experienced by an Alzheimer's patient.

The progression of Alzheimer's disease is typically broken down into 3 stages, sometimes preceded by a preliminary stage. The preliminary stage is characterized by mild cognitive impairment, which is worse than average for the person's age and is marked by episodes of complete memory loss. Such symptoms typically, though not definitively, progress to Alzheimer's within 2 to 5 years.

Movement through the 3 main stages of Alzheimer's takes between 7 and 14 years, with only 3 percent of patients living more than 14 years beyond diagnosis. The disease typically strikes later in life, when the patient is 60 or older, although a small percentage of patients show early onset in their 40s or even younger; this version of the disease has a strong genetic link.

The disease targets memory systems, destroying them almost in the order that they were built. At first, episodic memory of the most recently learned information is most likely to be impaired. There will also be instances of almost complete memory loss, a catastrophic loss of personal identity. The sufferer is usually aware the experience is not normal but is embarrassed to tell others about it.

Sometimes during the early stage, patients also become hyperactive. They may have serious insomnia and sometimes just feel the need to get out and walk. This need becomes dangerous when a loss of self-awareness occurs while a patient is walking alone. In many communities, Alzheimer's patients are asked to wear medical alert bracelets for this reason. The patient may also have language problems, both with finding words and language fluency in general. Semantic memory is breaking down. All of this combines to make this disease one that targets social relationships as it targets memory.

In the moderate stage of the disease, patients experience further deteriorations in both semantic and procedural memory. They forget how to brush their teeth, keep clean, get dressed, and so forth. They begin to lose their independence. Language becomes further impaired, wandering

becomes even more pronounced, and mood is greatly affected. The patient may also lose disease awareness at this stage, despite all that is happening.

In the advanced stage of Alzheimer's, patients are completely dependent on the care of others. Language is reduced to words or short phrases. Patients exhibit exhaustion and cannot perform even the simplest task without assistance. Sometime during this stage, patients become bedridden. Eventually they will pass away, though typically not from the disease itself.

Available medications can only provide a small reduction in symptoms; they cannot stop or even slow the disease.

Currently, we do not have a good understanding of Alzheimer's disease. We know that patients show abnormal clumps (called **amyloid plaques**) and tangled fibers (called **neurofibrillary tangles**) in their brains, the latter starting in an area called the entorhinal cortex and spreading to the hippocampus. As plaques and tangles spread, they interfere with the functioning of more and more healthy neurons. As neurons lose the ability to communicate, they die.

Available medications can only provide a small reduction in symptoms; they cannot stop or even slow the disease. Lifestyle may play a role in Alzheimer's prevention, as do genetics and early childhood environment. Behaviors with the most potential benefit include a Mediterranean diet, lots of cognitive stimulation (like playing chess and socializing), and medical marijuana. On the flip side, Alzheimer's disease is more prevalent in industrialized areas and among smokers, so avoiding such pollutants may help.

Technology may soon be able to help Alzheimer's patients fill in for some of their lost cognitive abilities. My students and I are currently working on such **cognitive prosthetics**. One example is a GPS-based software system housed in a mobile device like a phone that can detect when the patient is wandering and provide information and assistance to help them get safely home.

An approach like this is more crutch than cure, but it could also aid in the search for a cure when used in combination with drug trials to measure the frequency of wandering episodes among trial subjects. Some people worry that too much reliance on technology may be robbing us of useful cognitive exercise, but in the case of patients suffering from debilitating memory problems, it is hard to see such tools as anything but positive. ■

Important Terms

Alzheimer's disease: A degenerative neurological disorder characterized by memory loss caused by loss of cortical neurons, amyloid plaque formation, and neurofibrillary tangles.

amyloid plaque: Abnormal clumps of beta amyloid protein found in the brains of patients with Alzheimer's disease.

cognitive prosthetics: Technologies that help replace lost cognitive functions.

neurofibrillary tangles: Clumps of tau protein that are found in the brains of patients with Alzheimer's disease.

Suggested Reading

Baddeley, Kopelman, and Wilson, *The Handbook of Memory Disorders*.

Cole and Baecker, *Cognitive Prosthetics for Brain Injury*.

Gruetzner, *Alzheimer's: A Caregiver's Guide and Sourcebook*.

Wayman, *A Loving Approach to Dementia Care*.

Questions to Consider

1. If you saw someone who seemed lost and who you thought might be suffering from Alzheimer's disease, what would be the best way to try to help them?

2. To get a sense of how prevalent Alzheimer's disease is becoming, ask some of your friends if anyone in their family has it. I suspect you will be surprised at how many lives are being directly or indirectly affected.

Exercise

At various points in your day, imagine suddenly forgetting who you are, where you were going, and what you were doing. Imagine how it would feel to lose more and more of your conscious memories, starting from those you most recently acquired backward. So first you forget yesterday, then last week, then last year, then everything from just before the time you met your best friend (at which point that person becomes a stranger), and so forth. At what point in the process do you completely lose the sense of the person you now see in the mirror? When your most recent memory is of a decade ago, does the reflection you see make sense? Imagine remembering nothing from the past 2 decades … 3 decades … 4 decades. The actual progression of Alzheimer's is not that orderly, but is it any wonder that Alzheimer's patients become completely and utterly confused and that they lose all sense of who they are and what is happening to them?

That Powerful Glow of Warm Familiarity

Lecture 18

Past experiences affect us in ways we often underestimate. Through simple repetition, items come to be perceived fluently, and that fluent perception can make us think we are acting rationally when we are not. This happens most when we are making decisions based on little research or deep thought. Repetition can also form prototypes that are themselves processed fluently, even if we have never experienced the literal prototype.

We now turn from theoretical and empirical information about how memory works to think about the many ways memory influences our behavior every day, starting with the influence of familiarity, or **perceptual fluency**, the resonance of a current situation with our past experience.

When we experience something over and over, we become better—more fluent—at recognizing it. The semantic information we have about objects in the world is represented in the association cortex. In short, it allows us to know what it is we are seeing, hearing, and so forth. More accurately, the more experience we have with some object, the more quickly we are able to recognize it from its features.

The processes of perception themselves can be thought of in terms of procedural memory. Repeated experience viewing some particular stimulus enhances the fluency with which the stimulus is processed. But in this case, we subjectively experience this fluency as a positive emotional reaction.

We sometimes attribute perceptual fluency to past experience, but not always, and even when we do, we don’t always get the specific past experience right. Thus, feelings of familiarity are open to interpretation, and the interpretations we make can allow us to be fooled, or even to fool ourselves.

Experiments involving the **mere exposure effect** demonstrate dramatic effects related to simple exposure to a stimulus. When words are presented

to subjects via **rapid serial visual presentation**, the subjects felt like they saw the words but could not remember them. Yet recognition tests show that participants can make accurate guesses about what words they were shown.

What's interesting is, if you instead ask the test subject to categorize words in terms of how much they like them, they tend to like more of the presented words. The feeling of familiarity is undifferentiated; participants interpret or attribute the positive feeling in terms of whatever task is at hand. This is why politicians plaster their names on every available surface just before an election and advertisers throw their brand's name on everything: to increase your fluency and thus your associations with the name.

The success of perceptual fluency depends to a large extent on humans being relatively naive to its powerful effects. It has the most influence in contexts where we have little solid information to rely on. The scary thing is, these contexts are very common, and modern research supports the old saying, "If you say something often enough, it becomes true."

If conditions are right, the brain can be tricked into fluently processing things it has never actually seen.

If conditions are right, the brain can be tricked into fluently processing things it has never actually seen. Implicit memory, our tendency to extract the structure and regularities from stimuli, encodes structures even when they were never explicitly presented. So, for example, the constant presentation of female models who are medically 15 to 20 percent below a healthy weight for their height and age reinforces an idea that thin women are beautiful, even though it may be contrary to good health.

Prototypes like these are really just another type of script or schema, and as such they can be extremely useful in helping us negotiate our way through the world—if the stereotypes are valid. However, while we use the prototypes to guide our decisions, we do so in a manner that is often blind to accuracy of the experiences that gave rise to them. ■

Important Terms

mere exposure effect: The surprisingly strong memory effect of brief exposure to a stimulus, even when no effort was made to remember the stimulus.

perceptual fluency: Familiarity; the resonance between present and past experience.

rapid serial visual presentation: A technique used in memory experiments wherein a set of words is flashed before a subject so quickly that the subject feels he or she hasn't seen most of them.

Suggested Reading

Dill, *How Fantasy Becomes Reality*.

Fennis and Stroebe, *The Psychology of Advertising*.

Graf and Masson, *Implicit Memory*.

Questions to Consider

1. Now that you know about the effects of familiarity, do you think you will make your decisions any differently the next time you vote or go shopping?

2. Have you ever met someone from your home country while traveling abroad and felt that you really liked them? Why might this be the case? Do you think you would have liked them as much if you had met them just down the street from where you live?

Exercise

The next time you are watching television, notice how many commercials really say very little about the true merits of the product they are selling, instead only mentioning the name of the product and trying to associate it with things you already like. Does the prevalence of such commercials suggest that advertisers regard the influence of familiarity as more powerful than any rational claims they could make about why you should buy their product?

Déjà Vu and the Illusion of Memory

Lecture 19

Many people are inclined to attribute déjà vu to a metaphysical cause—a premonition, a message from God, and so on. But there are several sound this-worldly theories to explain the phenomenon. Most are related to our brains making mistakes in perceptual fluency, interpreting the unfamiliar as the familiar, either through priming, episodic memory degradation, or a parahippocampus glitch.

The experience of **déjà vu**—a French phrase meaning “already seen”—is a common but unsettling one. This sudden, overwhelming feeling of familiarity in a situation that we rationally know is brand new can seem almost mystical in the moment, but most scientific theories describe déjà vu as an illusion of memory.

Two common explanations of déjà vu are not memory based. The first suggests that déjà vu arises from random electrical stimulation in the temporal lobes, not unlike the stimulation epileptics experience right before a seizure. Another theory is that sensory information from each of our eyes or ears reaches our brains at a slightly different rate; when the message arrives from the slower eye, it feels familiar because we really have already seen it. The theory that déjà vu arises from a misattribution of perceptual fluency is a better fit for the evidence. Humans are very uncomfortable when something feels familiar and they don’t know why, so they feel compelled to attribute the familiarity to something.

Virtually all of the memory experiments that inform our understanding of déjà vu utilize the recognition memory test. Researchers are especially interested in the false alarms that occur on a recognition task. Some false alarms are caused by words with **semantic overlap**; for example, subjects who were shown the word “rose” might register a false sense of familiarity with “tulip.” If the text contains a mix of words that are in everyday use with more obscure words, they are more likely to falsely register any common words as familiar.

False alarms on a recognition test are interesting, but they are not really déjà vu. Déjà vu also includes that sense of oddness, the subjective creepy feeling. This is very hard, if not impossible, to re-create in a laboratory, so most theories of déjà vu will be just that—theories.

Another possible explanation for déjà vu is **priming**. Our memories are always preparing us for what we are about to experience; for example, you might start a conversation expecting a certain language to be spoken. This allows us to react more quickly and efficiently in any situation. Stimuli can prime us even when we are not aware of them. In déjà vu, priming may happen via a subconscious glance. If you see just enough of a scene to begin processing it, glance away for a moment, and then return to the original scene, your memory may already be primed for what it is seeing, even if you weren't aware of that first glance. You are left with an intense feeling of familiarity that you cannot attribute to anything.

Our memories are always preparing us for what we are about to experience. … Stimuli can prime us even when we are not aware of them.

Neuropsychological theories of déjà vu focus on a brain region just below the hippocampus called the **parahippocampus**. Imaging studies show that this region is active when stimuli feel familiar, irrespective of whether those stimuli are consciously recognized or not. So in brain terms, déjà vu may be a situation in which the parahippocampus is active but no conscious memory is retrieved because there is no memory to be retrieved.

Alternatively, the hologram theory of memory argues that memories, like holograms, are re-created out of bits of themselves; the smaller the bit, the more blurred the ultimate memory. In déjà vu, some small aspect of our current experience may be enough to retrieve a very blurry version of some past experience. If this ghost of a memory is strong enough, it may trigger brain regions that respond to familiarity without retrieving an episodic memory. A similar theory suggests that our indirect experiences—say, through books or movies—might be enough to trigger a strong sense

of familiarity that cannot be easily attributed to anything. Both of these are really alternate forms of the priming-attribution theory.

What do all these theories of déjà vu tell us about memory? For one thing, they tell us that declarative and nondeclarative forms of memory can become dissociated and that we can feel it when they do. The reverse can happen, too. If you take any word and repeat it over and over and over, eventually that word will not feel familiar anymore. Experiences like this are called **jamais vu**, which translates to "never seen." The Capgras delusion is an extreme form of this. ■

Important Terms

déjà vu: A disquietingly strong sense that a new event has already been experienced; from the French term meaning "already seen."

jamais vu: A disquietingly strong sense that a familiar event has never been experienced before; from the French term meaning "never seen."

priming: A process of being prepared for a stimulus by some previous experience.

parahippocampus: A brain region involved in sensations of familiarity.

semantic overlap: In a recognition test, a word that evokes a sense of familiarity because it has a meaning similar to or belongs in a category with a word presented earlier (e.g., red and crimson; rose and tulip).

Suggested Reading

Graf and Masson, *Implicit Memory*.

Koonce, *The Deja Vu Experience*.

Questions to Consider

1. Why do humans seem to need to explain every experience in some way? Which explanation of déjà vu do you find most convincing from your own experience or what you have heard about déjà vu from others?

2. So called date-rape drugs cause the body to release the hormones usually released by physical attraction. Someone unaware of being drugged might misattribute their response to the drug as true feelings of attraction for someone who happens to be nearby. How is this like the déjà vu theories described in this lecture?

Exercise

Can you think of someone who you will likely run into in the near future? If so, think about that future meeting now, and practice something you will say to that person—anything, even something simple like "Good morning. Very nice to see you today." Imagine yourself meeting that person and saying that as many times as possible. Then, when you do meet, go right up and say those words just as you have been practicing. What does it feel like when you say the words? How is this situation like the one that theoretically produces déjà vu, and how is it different?

Recovered Memories or False Memories?

Lecture 20

Human memory is not like a camera; it does not store and replay perfect copies of events. We all forget or misremember details of our past, but astonishingly, we can even "remember" events that never occurred at all. These so-called false memories are more than a quirk of human psychology; they can have powerful effects on our interpersonal relationships, as well as profound ramifications within the legal and judicial system.

Our episodic memories, just like our sense of familiarity, can sometimes go awry for some of the same broad reasons. Memories so fundamentally false are fascinating, raising all sorts of questions about the basis of conscious memory.

In the 1980s and 1990s, more and more prosecutors began submitting witnesses' **recovered memories** as evidence in major cases, but not without stirring controversy. Even as these uses became more frequent, debate flared over whether recovered memories are accurate or whether they are creations of the therapeutic process.

The idea of repressed and recovered memories is as old as psychology itself. Sigmund Freud believed that mental health issues are best viewed as symptoms of some deep internal conflict. As such, a therapist should not attempt to treat the symptoms but to uncover the conflict and help the patient acknowledge and deal with it. This theory is based on 2 assumptions: first, that the patient does not know what the conflict could be, and second, that active cognitive processes exist to keep these conflicts buried.

Given these assumptions, psychoanalysts believe that the only way to uncover the conflict is to use indirect methods that gently probe the mind and allow the painful memories to expose themselves, methods like inkblot tests and free association. If therapy goes well, the patient reaches **catharsis**, a realization of the internal conflict that makes all the patient's troubles

make sense. The memories obtained from this process tend to feel clear and accurate, and the patient is certain they are real.

Unfortunately, these assumptions are not based on scientific findings, and doubts about them have only increased over time. The first doubts were raised by psychologist James Deese in the late 1950s; his research suggested that people could have episodic memories for things that never occurred. In the 1980s and 1990s, psychologists Roddy Roediger and Kathleen McDermott returned to Deese's findings and devised a method for creating false memories that bears striking similarities to aspects of clinical psychotherapy.

After undergoing Roediger and McDermott's false memory experiment, some people are more confident of their false memories than they are of their real memories. Roediger and McDermott's experiments also suggest that even a well-meaning therapist can make assumptions about what the patient is suppressing and inadvertently lead the patient to create a memory that fulfills those expectations—a form of priming.

Repressed memory is one of the central principles of psychoanalytic theory, and recovering or releasing them is the main goal of talk therapy.

That said, just because you can create false memories in a lab doesn't prove that all memories recovered in a psychoanalytic setting are false. Dismissing all recovered memories risks re-victimizing the patient and compounding his or her mental health issues. It is a problem with no easy solution; the justice system has compromised by continuing to allow recovered memories as testimony but requiring them to be backed up by other forms of evidence.

Separating real from imagined events means distinguishing between mental experiences prompted by external events versus mental experiences prompted by internal events—things we think or imagine. What is quite fascinating, given how memory seems to work, is how well most of us do distinguish real from imagined most of the time. Episodic memory can go drastically astray because we exist in highly complex environments that require us to switch attention rapidly among various stimuli that our memory must piece together. But our memory systems hate loose ends, and it is in tying those ends up that our memories sometimes fail us. ■

Important Terms

catharsis: In psychoanalytic theory, the release of blocked psychic energy, typically by way of free association and sustained talk.

recovered memory: A memory, usually a traumatic one, thought unrecoverable that is retrieved with the aid of hypnosis or psychoanalytic techniques.

Suggested Reading

Bjorklund, *False-Memory Creation in Children and Adults*.

Brainerd and Reyna, *The Science of False Memory*.

Davies and Dalgleish, *Recovered Memories*.

Sandler, Fonagy, and Baddeley, *Recovered Memories of Abuse*.

Questions to Consider

1. Have you ever suddenly remembered something that you feel had been forgotten for years? If so, does this mean that memories can be repressed, or is there some other explanation?

2. Have you ever been in the situation where you had to ask someone if you had already told them some bit of information or not? Or maybe you wondered whether something really happened or whether you merely dreamed about it happening? How are these situations similar or different from the false memory situation described in the lecture?

Exercise

Here is a list of words related to sleep: bed, tired, sheet, blanket, night, exhausted, snooze, pillow, refresh, doze. Read those to a friend one day and ask them to try to remember them. Then test them the next day and include the word "sleep" in the test. Do they claim to remember "sleep" being in the original list? How confident are they in their memory?

Mind the Gaps! Memory as Reconstruction

Lecture 21

The analogy of retrieving memories from our brains the way one retrieves a book from a shelf is actually a false one; in reality, every time we remember an event, we are reconstructing it from specifics stored in our episodic memory and general knowledge of the world stored in our semantic memory. In most contexts, this system is elegantly efficient, but it is also prone to minor errors that may have not-so-minor consequences.

In the late 19th century, Russian neuropsychiatrist Sergey Korsakov discovered that many of his patients who were alcoholics or malnourished had severe trouble laying down new episodic memories. He also noted that these patients had a tendency to confabulate, yet they weren't intending to deceive anyone. These observations were some of our first clues to the nature of memory retrieval.

A few decades later, Cambridge University psychologist Sir Frederic Bartlett tested people's ability to recall details by reciting an American Indian folktale to English men and women and asking them to repeat what they had heard. The test subjects were likely to remember aspects of the story that were culturally familiar but tended to forget or alter unfamiliar details; for example, they tended to Christianize the story's spiritual and supernatural aspects.

Bartlett's conclusion was that we do not retrieve memories as complete episodes but reconstruct them by piecing together newly stored bits with things we already know. In other words, our semantic memories fill in gaps within our episodic memories. On close examination, this system makes a lot of sense; because most of the details of any experience are mundane, they can be left to semantic memory, while the episodic memory takes care of unusual or unique details. The problem is that people have trouble knowing the difference between the facts and the filler.

So we know memories are often inaccurate, and that these inaccuracies are due to the reconstructive nature of memory. We also know that these inaccuracies may be accompanied by high levels of confidence. Most of the time, these errors are trivial, but in a legal context, errors in memory can have huge consequences.

Every year, more than 70,000 Americans are charged with crimes solely on the basis of eyewitness testimony—that is, on the basis of episodic memory—and studies show that eyewitness testimony is the single most convincing form of evidence for the average jury, even when that testimony has been discredited. This is worrisome because a number of studies demonstrate how inaccurate eyewitnesses often are. Also, jurors are heavily swayed by a witness's appearance of confidence, and we know how confident people can be about their false memories.

The American justice system does what it can to find jurors with unaltered memories and weak biases and then to control the details of the case those

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Juries put more faith in eyewitness testimony—another human's episodic memory—than any other form of evidence.

jurors are exposed to. This begins with voir dire, an Old French term that means "to speak the truth." Lawyers get to interview prospective jurors, and with highly publicized cases, a judge may go so far as to order jury sequestration before or during the trial.

Lawyers also sometimes try to use memory re-creation to their advantage through carefully choosing the way they word their questions. Most of us know this as "leading the witness"—namely, asking a question in a way that suggests a certain answer.

It's important to emphasize that these sorts of errors don't just happen in the courtroom; they happen to each of us on a daily basis. In the vast majority of cases, the important aspects of our episodic memories are correct—"important" meaning the aspects we thought were important at the time of encoding. Semantic memory pieces those aspects together to provide a seamless replaying of the event.

So why did Dr. Korsakov's malnourished patients confabulate for no apparent reason? Because their condition caused thiamine deficiency, which damaged the hippocampus, they simply had less accurate memories to go on. They tried to make sense of the bits they had; they just weren't very good at it. ■

Suggested Reading

Best and Intons-Peterson, *Memory Distortions and Their Prevention*.

Memon, Vrij, and Bull, *Psychology and Law*.

Schacter, *The Seven Sins of Memory*.

Questions to Consider

1. The more you understand how things work in various contexts, the better you are able to fill in the gaps between remembered details, and the more vivid your memory will be. What does this say about the link between the accuracy of memory and how vivid, and therefore real, it might seem?

2. The next time you and someone else have very different memories of some event, pay attention to the specific bits you disagree about. Are these bits things you likely felt were really important at the time of encoding?

Exercise

Find the folktale Sir Frederic Bartlett told to his subjects, “The War of the Ghosts,” online. Read it once, then in about a week try to rewrite it. Compare your recounting to the original. Even knowing all you now know about memory, do you still make interesting errors of omission and regularization?

How We Choose What's Important to Remember

Lecture 22

Now that we know our episodic memory only encodes part of every experience, we must ask how and why those parts are chosen while others are allowed to fade away. When we allow our brains to do the choosing (which is most of the time), they encode elements that are most similar to our previous experiences and elements that immediately affect our survival. However, we can, with some effort, choose what we encode as well.

Effective deliberate memory encoding takes effort. We have so many experiences in the course of any given day that we simply cannot engage in this sort of effort for each one. Therefore, the brain uses 2 main criteria to decide what is important: personal relevance and survival relevance.

Things that are personally relevant to us are easy to associate with other things in our life and in our existing memories, and therefore they are easier to organize. We also think more about the relevant, which increases the chance such things will enter our episodic memories. The problem with this is that what is relevant now might not be relevant later.

There are other cases when relevance is thrust upon us. Perhaps the most extreme example is the **weapon focus effect**. When someone is the victim of or witness to a crime, that person can often describe the weapon better than he or she can describe the perpetrator. At that moment in time, the weapon literally means the difference between life and death, so the person has a hard time looking at or thinking about anything else. There's a straightforward evolutionary explanation for the weapon focus effect: We likely descend from those who best attended to factors in their environment linked to survival.

In situations of extreme stress, it is easy to tell if an organism—humans included—has recognized some stimulus as relevant to their survival. We all have 2 modes of central nervous system operation: the **parasympathetic**

mode and the **sympathetic mode**. We can only be in one of these modes at any given time.

- The parasympathetic mode, which we are in when we are relaxed and calm, is concerned with the long-term survival of the body. When it is in control, heart rate slows, muscles relax, and basic housekeeping functions like digestion kick into gear.

- When a crisis occurs—say, you hear a loud explosion—the sympathetic mode takes over. Heart rate increases, respiration increases, adrenalin pulses through the body, attention snaps to the situation at hand. You are ready to fight or flee.

The part of the brain that flips the switch between the modes is the **amygdala**, an almond-shaped region of the midbrain whose primary job is to sense threat in the environment. Evidence from fMRI studies show that when the amygdala senses danger, it also activates the hippocampus, which results in deeper encoding of everything that is happening. This interaction is the basis for the **emotional binding hypothesis**, the notion that the amygdala's job is not just to get us through the present crisis but to ensure we encode the experience to improve our chances of survival in the future.

The amygdala's job is not just to get us through the present crisis but to ensure we encode the experience to improve our chances of survival in the future.

Even if you've never been in a major crisis yourself, you likely have a vivid memory of crises you experienced through the news. Many Americans say they remember the tiniest details of where they were and what they were doing when they heard the news of the terrorist attacks of September 11, 2001. Such detailed mental snapshots are called **flashbulb memories**.

Are flashbulb memories really as accurate as they seem? The experimental data is mixed. Studies suggest that for people who felt more personally attached to the event (say, people who had friends or family scheduled to fly

that September 11), flashbulb memories retain greater accuracy over longer periods, so personal relevance may be a factor. Then again, those with a personal connection to the event are also more likely to tell many people their story in the hours and days right after the event, so perhaps the stronger encoding comes from repetition. Note also that such cumulative retellings get attached to and may distort our original memories, so even those flashbulb memories may lose accuracy over time.

Aside from these automatic processes of encoding, you can to some extent take control of which details enter your episodic memory by using the basic mnemonic techniques discussed early in this course: association, dual encoding, and repetition. If you want to remember the positive events of your life, then cherish them as they occur by organizing them and sharing them with others. ■

Important Terms

amygdala: An almond-shaped region of the brain involved in the processing of emotions, particularly fear.

emotional binding hypothesis: The notion that memories with powerful emotional content are more strongly encoded than those without.

flashbulb memory: A brief and highly detailed memory usually associated with a traumatic experience; often found in patients with post-traumatic stress disorder.

parasympathetic mode: The state of the nervous system during periods of calm, associated with “rest and digest” functions.

sympathetic mode: The state of the nervous system during crisis situations, associated with the “fight or flight” response.

weapon focus effect: The tendency of a witness to or victim of a crime to be able to recall details of a weapon (i.e., the immediate perceived threat) more clearly than he or she can recall the perpetrator.

Suggested Reading

Mason, Kohn, and Clark, *The Memory Workbook*.

Nelson and Gilbert, *Harvard Medical School Guide to Achieving Optimal Memory*.

Uttl, Ohta, and Siegenthaler. *Memory and Emotion*.

Questions to Consider

1. The amygdala triggers the body's stress response when it is active. Without an amygdala, we would never feel fear or worry. Why don`t we all just have our amygdalas removed?

2. I mentioned that people who were in horrific crashes and ended up concussed often have trouble remembering the terrifying events just prior to their accident, and yet people who witness terrifying events without being subsequently concussed remember the events very clearly. What does this suggest about the importance of consolidation to the effects of emotion on memory?

Exercise

The next time you embark on some sort of adventure, test the rule that 3 things will go wrong and count them off as they do. Does this somehow make them less annoying and less worthy of dwelling on and remembering? Then think about what you might do to remember more vividly the highlights from your adventure.

Aging, Memory, and Cognitive Transition
Lecture 23

Our semantic and procedural memory systems continue to function quite effectively into normal old age. While early researchers turned up dramatic effects of aging on episodic memory, a lot of those studies were confounded by time-of-day effects; it turns out that the changes are small and are better thought of as a transition than a decline. Some aspects of memory, including creativity and big-picture thinking, actually improve with age.

As we age, many of us feel our memories are less accurate than they once were, and we often look for ways to minimize memory deterioration. But as you are now aware, memory is not a single thing. When it comes to the question of memory declining with age, we must realize that any one question about memory—even just long-term memory—is actually 3 questions.

For the most part, procedural and semantic memory show little decline with age. Problems with procedures usually have little to do with memory and more to do with the physical effects of aging—arthritis, vision or hearing loss, and the like. And for the most part, we don't complain that we're losing our semantic memory; we can still recite the multiplication tables we learned as children. The classic complaint is a decline in episodic memory, in terms of both recall and encoding.

One interesting feature of this episodic memory loss is a tendency among older people to tell the same story to the same person over and over, forgetting that they've told it before. It has been suggested that this is actually an evolutionary advantage, ensuring that each generation remembers and passes on important information to the next.

When does an individual's episodic memory begin to decline, and how dramatic is the impairment? The earliest major studies on this, performed in the late 1980s, suggested that memory decline began as early as the age of 50 and was rapid and dramatic. But in the early 1990s, psychologist

Lynn Hasher noticed something about these studies. One of her areas of expertise was **circadian rhythms**, the natural hormone and neurochemical cycles of the human body, which affect both physical and cognitive behavior. Knowing that our circadian rhythms shift as we age—in adolescence, we are more likely to be night owls, and as we age, we become morning people—she noted that most of these tests were performed in the afternoon and evening, when the graduate students conducting the tests and the young subjects were at their mental peak but the older subjects were becoming tired.

Crossword puzzles are good for sharpening certain memory skills, but better still are complex hobbies that engage more than one memory system at a time.

Hasher conducted similar studies, but she ran them both early and late in the day. She discovered that, when you control for the time variable, the performance gap between old and young subjects shrank considerably, although it did not disappear. What's more, the data indicated that the time of day had a far stronger effect on memory in both groups than did age. Hasher and her colleagues' further studies also revealed that younger people were better at focusing their attention, while older people were more easily distracted by extraneous detail. Interestingly, you see this same contrast between so-called normal people and creative people—writers, composers, painters, and so on.

From this evidence, Hasher suggested that the way our brains change as we age is not a form of cognitive decline; rather, it is cognitive transition. In most cases, the way we interact with the world changes as we age. We do not need to attend to as many things at once. As a result, we literally change the way we interact with the world, and we spend less time thinking about details and more time thinking about the big picture. Accurate episodic

memory, of course, is all about the details, so episodic memory does show a slight decline. However, creativity shows an improvement, as demonstrated by how many people take up creative hobbies during retirement. So the way our minds change during normal aging is not so much a loss as a trade-off.

That said, it is possible to sharpen our episodic memory as we age. Many researchers have recommended brain exercise like crossword puzzles, Sudoku, and so on, but more complex and general hobbies can be even more beneficial—hobbies like dancing, painting, or writing, which require constantly learning new things and repeatedly recalling what you have learned. ■

Important Term

circadian rhythms: The daily ebb and flow cycles of hormones and neurotransmitters.

Suggested Reading

Craik and Salthouse, *The Handbook of Aging and Cognition*.

Kausler, *Learning and Memory in Normal Aging*.

Langone, *Growing Older*.

Questions to Consider

1. If you could choose a life where you were very worried about details all the time but as a result were really good at remembering details, is that the sort of life you would choose?

2. We say that you can't teach an old dog new tricks, and yet procedural and implicit memory seem not to decline with age. As you've gotten older, have you tried learning "tricks" unrelated to your existing skills? Which seem easiest, and which seem more challenging?

Exercise

As you go about your day, think about the various tasks you perform. Which ones exercise which forms of memory? Is there any form of memory that you are not exercising much within your current behaviors? Given that semantic, procedural, and implicit memory are so important to effective functioning in the present, episodic memory is often the one form of memory that gets the least exercise. Could you think of some new behavior that you might like that would fill the gaps in your current memory workout? If it could become some new hobby or activity that you truly enjoy, you would be keeping your mind young in a way that would be easy to continue.

The Monster at the End of the Book
Lecture 24

Now that you understand much more about the many-headed beast that is human memory, you can dismiss the simple question "Can I improve my memory?" and replace it with the more sophisticated "Can I remember what I want, and forget what I want?" In suitably complex fashion, the answer is "sometimes"; more important may be the question of whether or not you really want to change your memory skills at all.

By now, you're aware that the simple way you may have thought of memory before taking this course was wrong. Memory takes many different forms, some of which you might never have even recognized as memory. You also know that the different memory systems interact in complex ways that defy most people's preconceptions. Therefore, you also know that the simple question "Can I improve my memory?" and the simple answer "yes" don't even start to cover the issue.

What's more, we can't ask the question until we define what we mean by "improve." If all you want is to remember more, then there are several options. You can exercise your memory the same way you exercise a muscle—by using it. The best mental exercises involve memory cross-training—that is, tasks that work as many declarative and nondeclarative memory systems at once as possible. Memory consolidation benefits from getting good sleep. Eating the right foods—foods rich in omega-3 fatty acids, thiamine, and vitamin B_{12}—are good for brain health in general and memory in particular. But our initial goal begs the question: Do you really want to increase how much you remember?

Before you answer, consider the case of Jill Price, a woman with a specific type of obsessive-compulsive disorder that causes her to obsessively encode her episodic memories. She has near-perfect recall for everything that she has ever experienced, including the painful incidents most of us would rather forget, which haunt her life and relationships as if they happened yesterday.

How about the famous “mnemonist” known only as S., who had a condition called **synesthesia** that, in laymen’s terms, cross-wired his senses. Every word S. heard also registered as a visual image, usually a color. In other words, his brain automatically performed the sort of dual coding we have to train ourselves to use. Sounds like a good thing, except like Jill Price, he had trouble forgetting painful or trivial things he’d rather dismiss. His unique perspective on reality also made him something of a social misfit and even made it hard for him to hold down a job. For most of us, the price of this kind of memory would be too great.

Can we break the strong links the amygdala and hippocampus forged in the heat of crisis?

The lesson is clear: We don’t want to have a stronger memory; we want to have a selectively stronger memory. You’ve already learned a bit about how and why to take up active encoding, but how do you decide what to encode? It may seem obvious that you’d want to encode the details of your wedding day strongly—unless the marriage doesn’t work out. What we wanted to remember in the past isn’t always what we want or need to remember in the future.

So can we forget things we’ve made an effort to encode, or can we forget painful or paralyzing flashbulb memories of the sort that cause **post-traumatic stress disorder (PTSD)**? Can we break the strong links the amygdala and hippocampus forged in the heat of crisis?

For some strong, painful memories, you can avoid the cues that trigger them—avoid the people, places, songs, and so forth that bring them to mind. Unfortunately, that’s not viable for people with PTSD, who can have unavoidable triggers like loud noises or bright lights. Researchers are therefore looking for a way to block the emotional response to these memories, even if they can’t remove the memories themselves. Drugs called **beta-blockers** show a lot of potential in this area.

Still, there may be times when we want to remember an event we did not deeply encode originally. Often, this means you have made a choice (consciously or subconsciously) about what to pay attention to in a

situation, only to be disappointed that you have lost a "more important" detail. Our brains are performing a delicate balancing act all the time. Is this an act we want to interfere with? Maybe you don't have to "improve" your memory at all.

Throughout this course, we have challenged the notion of a single thing called memory and talked about memory as a collection of systems that exist within a single body. So let's end this course by challenging that notion as well: Memories are passed from person to person, implicitly by example, explicitly with the help of language. Memories also are transmitted across time and space thanks to the printed word and, increasingly, digital media. We can even point to something like communal memories, existing in diverse formats from museums to urban legends. Memories like these allow us a glimpse of what it means to be immortal. To be remembered is to be alive, even if that new life is in the mind and body of another. Thus memory not only guides us through life; it sustains us even after death. ■

Important Terms

beta-blocker: A drug that blocks certain neurological signals to the heart, preventing it from speeding up under conditions of stress.

post-traumatic stress disorder (PTSD): A disorder characterized by extreme anxiety and fear in response to remembering a traumatic event.

synesthesia: A condition in which a sensory stimulus (say, a sound) is perceived by more than one sense (say, as both a sound and a color).

Suggested Reading

McGaugh, *Memory and Emotion*.

Nelson and Gilbert, *Harvard Medical School Guide to Achieving Optimal Memory*.

Woll, *Everyday Thinking*.

Questions to Consider

1. Now that you understand the many different ways that memory systems contribute to human behavior, what answer will you give the next time someone asks if it is possible to improve memory? What if the person wants a quick answer, something you can express in a minute or two?

2. At encoding, we identify details we want preserved in memory; the more details we encode deeply, the more our memory of the event will match the actual event. But deep encoding takes time and effort, so we only worry about so many details. For comparison, let's say you have a good friend who is willing to shop for you. Suppose in one case you give your shopper very few details about what you would like ("I'd like a medium shirt."), but in another case, you give a lot of details ("I'd like a blue shirt with some white striping and an Asian-style collar that is fitted and made of a material that can be easily washed."). In either case, the shopper ultimately comes back with a shirt for you. How closely will the shirt match with what you hoped for? Compare this process with the way memory works.

Exercise

You just invested a lot of time listening to this course on memory, and I hope you have learned a lot. But now what can you do to maximize the chance that you will remember all you have learned?

One sort of mnemonic that is sometimes used in educational contexts like this is called a concept map. First, you think of all the concepts you have learned in a course and write them down. You might include such concepts as episodic memory, semantic memory, procedural memory, implicit memory, sensory memory, familiarity, frontal lobes, hippocampus, amnesia, Alzheimer's disease, reconstruction, déjà vu, animals, and so forth. Next, take these concepts and link them in ways that represent connections, perhaps also labeling the links in ways that make the connections explicit. These connections, or associations, allow one to see the concepts at a higher level, seeing interconnections and lacks of connections.

If you really want to remember a course, the conclusion is a perfect time to create a concept map. We've even provided a blank space on the page for you to use.

Use this page to draw your own concept map.

Glossary

agnosia: The failure to comprehend the meaning or function of things otherwise correctly and accurately perceived.

Alzheimer’s disease: A degenerative neurological disorder characterized by memory loss caused by loss of cortical neurons, amyloid plaque formation, and neurofibrillary tangles.

amygdala: An almond-shaped region of the brain involved in the processing of emotions, particularly fear.

amyloid plaque: Abnormal clumps of beta amyloid protein found in the brains of patients with Alzheimer’s disease.

anterograde amnesia: The inability to form new memories after a neurological event.

basal ganglia: A group of brain regions associated with motor control, both voluntary and involuntary.

beta-blocker: A drug that blocks certain neurological signals to the heart, preventing it from speeding up under conditions of stress.

Broca’s area: The brain region involved in speech production.

Capgras delusions: A failure of memory that allows a person to recognize objects or people they have encountered before, but recognition is accompanied by a strong sensation that those objects or people are unfamiliar.

capture error: A situation in which we are consciously trying to not perform a strong procedural memory (i.e., a habit) but are unable to stop.

catharsis: In psychoanalytic theory, the release of blocked psychic energy, typically by way of free-association and sustained talk.

childhood amnesia: The human inability to encode episodic memories before about the age of 3.

circadian rhythms: The daily ebb and flow cycles of hormones and neurotransmitters.

classical conditioning: The encoding of procedural memory via the implicit memory system.

cognitive prosthetics: Technologies that help replace lost cognitive functions.

constructivist learning: The principle that it is easier to learn structure through direct experience of the structure rather than by explanation.

cortex: The outer mantle of the cerebrum.

declarative memory: Memory systems used deliberately to produce a clear, conscious answer to some query; these systems include episodic and semantic memory.

déjà vu: A disquietingly strong sense that a new event has already been experienced; from the French term meaning "already seen."

dorsolateral prefrontal cortex: The area of the frontal lobe where current theory indicates that working memory resides.

dual coding: The process of relating a new piece of information we wish to remember with both an image and a word to increase the ways we can retrieve the information later.

echoic memory: The ability to hold or recall a sound in one's mind; the auditory form of sensory memory.

emotional binding hypothesis: The notion that memories with powerful emotional content are more strongly encoded than those without.

episodic memory: Memories of specific, individual events, as opposed to general knowledge.

flashbulb memory: A brief and highly detailed memory usually associated with a traumatic experience; often found in patients with post-traumatic stress disorder.

forgetting curve: A mathematical function that predicts the time required to memorize, forget, and re-encode a set of data through rote memorization.

frontal lobe: The lobe at the front of the cortex involved in decision making, impulse control, and long-term planning.

functional magnetic resonance imaging (fMRI): An imaging process that uses magnets to create detailed images of which areas of the brain are active during certain tasks by showing the blood flow to each region.

habit: A form of procedural memory that is so well formed the actor is no longer in control of whether or not he or she performs it.

habituation: An acquired tolerance for a stimulus in an environment.

hippocampus: A region of the midbrain that allows the transfer of working memory into permanent storage and may coordinate the simultaneous activation of various memory systems.

iconic memory: The ability to hold or recall an image in one's mind; the visual form of sensory memory.

implicit memory: Memories encoded by repeated experience within some context but without a deliberate attempt at encoding; contrast with **rote memorization**.

jamais vu: A disquietingly strong sense that a familiar event has never been experienced before; from the French term meaning "never seen."

long-term potentiation: Enhanced connectivity between brain regions as a result of new experiences. *See* **neural plasticity**.

mere exposure effect: The surprisingly strong memory effect of brief exposure to a stimulus, even when no effort was made to remember the stimulus.

method of loci: A memory-encoding technique that relates an unfamiliar set of data to a familiar set of connected data, the most common example being places along a route; by recalling the familiar information, we can quickly bring to mind the new information.

modeling: Learning by imitation; specifically, an infant's mimicry of others' facial expressions.

neural network: A system of on/off switches interconnected in such a way as to imitate the structure of the brain or a region of the brain.

neural plasticity: The idea that the brain undergoes physical changes, specifically enhanced connections between brain regions, as a result of learning. *See* **long-term potentiation**.

neurofibrillary tangles: Clumps of tau protein that are found in the brains of patients with Alzheimer's disease.

nodes: The switches in a neural network that stand in for the brain's neurons.

nondeclarative memory: Memory systems used with little or no conscious mediation, such asd procedural and implicit memory.

parahippocampus: A brain region involved in sensations of familiarity.

parallel distributed processing: A form of neural network processing where the overall pattern of ons and offs is more important than the on/off state of any one node.

parasympathetic mode: The state of the nervous system during periods of calm, associated with "rest and digest" functions.

parietal lobe: The lobe at the top of the cortex that contains areas for processing sensory and spatial information.

perceptual fluency: Familiarity; the resonance between present and past experience.

phonological loop: The ability of the working memory system to recall and repeat a sound; one's inner voice.

post-traumatic stress disorder (PTSD): A disorder characterized by extreme anxiety and fear in response to remembering a traumatic event.

primacy effect: Better encoding and recall of the beginning of a list or series of events.

priming: A process of being prepared for a stimulus by some previous experience.

proactive interference: A previous experience that prevents successful encoding or recall of a similar piece of information.

procedural memory: The body's mastery of a physical routine; often called muscle memory.

prosopagnosia: The inability to recognize faces, despite being able to recognize other objects without difficulty, caused by damage to the fusiform gyrus.

prospective memory: Giving oneself instructions to remember or do something in the future.

rapid eye movement (REM) sleep: The sleep state during which dreaming occurs.

rapid serial visual presentation: A technique used in memory experiments wherein a set of words is flashed before a subject so quickly that the subject feels he or she hasn't seen most of them.

recency effect: Better recall of the most recently encoded information.

recovered memory: The retrieval of a memory, usually a traumatic one, thought unrecoverable, usually with the aid of hypnosis or psychoanalytic techniques.

REM atonia: The temporary state of paralysis that occurs during REM sleep that prevents us from acting out our dreams.

retrieval failure: Forgetting; that is, when we cannot recall a piece of information, usually because it was encoded without good retrieval cues.

retroactive interference: An experience that weakens the encoding or recall of a previously memorized piece of information.

retrograde amnesia: The loss of memories from before a triggering neurological event.

rote memorization: Memorization through repetition.

saccades: Swift glances moving from object to object in a scene that our iconic memories use to piece together a whole.

script theory: The idea that social theory is learned via implicit memory.

semantic memory: General knowledge about the world learned through repeated exposure to the information, as opposed to memories of specific events.

semantic overlap: In a recognition test, a word that evokes a sense of familiarity because it has a meaning similar to or belongs in a category with a word presented earlier (e.g., red and crimson; rose and tulip).

sensory memory: A temporarily retained impression of a sensory stimulus.

slow-wave sleep: The deepest stage of sleep, in which memory consolidation occurs.

state-dependent memory: A memory whose recall is improved by re-creating the emotional context in which it was learned.

striatum: A brain region associated with procedural memory.

sympathetic mode: The state of the nervous system during crisis situations, associated with the “fight or flight” response.

synaptic pruning: The removal of weak brain cell connections to make way for new ones that occurs at least twice in normal, healthy humans: once in adolescence and once in old age.

synesthesia: A condition in which a sensory stimulus (say, a sound) is perceived by more than one sense (say, as both a sound and a color).

tactile memory (a.k.a. **haptic memory**): The lingering impression of something we have touched or been touched by; a form of sensory memory.

temporary graded amnesia: The temporary loss of memory of events leading up to the triggering neurological event; the victim’s older memories return before the more recent ones, and events immediately before the event may never return (e.g., a concussion patient may never remember being hit on the head).

visual-spatial sketchpad: The ability of the working memory system to re-create and explore a place or object in iconic memory.

weapon focus effect: The tendency of a witness to or victim of a crime to be able to recall details of a weapon (i.e., the immediate perceived threat) more clearly than he or she can recall the perpetrator.

Wernicke’s area: The brain region involved in language recognition.

working memory: Sometimes called short-term memory, a memory system used for both temporary storage and as a mental workspace where information from other systems is processed.

Bibliography

Note: For those wondering where to begin, there are 4 books below that would provide a great starting point. Each has a different style and focus. Baddeley's *Essentials of Human Memory* provides a great overview of all memory systems; Graf and Masson's *Implicit Memory* focuses more specifically on one of the most overlooked aspects of memory; Foer's *Moonwalking with Einstein* is aimed at a general audience and focuses on mnemonic techniques; and Matthews and McQuain's *Bard on the Brain* provides a witty and informative look at brain imaging and memory. Together, they offer a fresh sampling from the complex and fascinating world of memory.

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Vanderwolf, C. H. *The Evolving Brain: The Mind and the Neural Control of Behavior*. New York: Springer, 2010. This book focuses primarily on the link between the brain and the systems it uses to voluntarily control behavior.

Vandierendonck, Andre, and Arnaud Szmalec. *Spatial Working Memory*. New York: Psychology Press, 2011. In contrast to other books in this bibliography about working memory, this one really focuses on the visuo-spatial scratchpad, what others sometimes term spatial working memory.

Wayman, Laura. *A Loving Approach to Dementia Care: Making Meaningful Connections with the Person Who Has Alzheimer's Disease or Other Dementia or Memory Loss*. Baltimore, MD: The Johns Hopkins University Press, 2011. Advice from someone who has provided care for Alzheimer's

patients and for patients of memory loss generally, and who has also worked with other caregivers. This book represents accumulated wisdom about how best to deal with the challenges that arise in a manner that attempts to preserve the loving connections between caregiver and patient.

Weingartner, Herbert, and Elizabeth S. Parker. *Memory Consolidation: Psychobiology of Cognition*. Hove, UK: Psychology Press, 1984. This book outlines some of the neurochemical interactions that may underlie the consolidation of memories over time.

Woll, Stanley. *Everyday Thinking: Memory, Reasoning, and Judgment in the Real World*. Hove, UK: Psychology Press, 2001. This book starts from the real world, highlighting various situations and how they map onto research on memory, reasoning, and decision making. As such, it provides a larger cognitive perspective on how basic processes, including but not exclusively those related to memory, play out when considered outside of laboratory contexts.

Internet Resources:

The Brain from Top to Bottom. http://thebrain.mcgill.ca. This site focuses on the link between your brain and various cognitive abilities, memory included. It also allows you to vary the level of explanation from beginner to advanced.

"Memory Improvement Techniques." *Mindtools*. http://www.mindtools.com/memory.html. This site focuses on strategies for memory improvement. It includes a detailed description of a number of mnemonic techniques.

"Psych Basics: Memory" *Psychology Today Online.* http://www.psychologytoday.com/basics/memory. A nice collection of articles originally published in *Psychology Today* that are relevant to memory issues. It includes advice on how to maximize your memory along with general information about memory presented for a lay audience.

On Memory: A Caregiver's Guide to Alzheimer's Disease. http://www.onmemory.ca/en/home. This site provides a very rich caregivers guide to

Alzheimer's disease and is especially useful for those who might be worried that a loved one is in the early stages. It includes a discussion of signs to look for, when one should consult a doctor, and the sort of information the doctor will want to know. However, it also includes many videos, stories, and advice relevant not only to caring for patients, but also for care for the caregiver.

The Memory Exhibition: Memory Games and More. http://www.exploratorium.edu/memory. This site is now more than 10 years old, but it contains many really nice demonstrations and animations related to memory.

"Memory." *Medline Plus*. http://www.nlm.nih.gov/medlineplus/memory.html. This medical resource focuses on problems with memory, ranging from Alzheimer's disease to common forms of forgetting. It offers information, tips, and advice, as well as information about the medical processes related to various disorders.

"Learning and Memory." *Big Dog & Little Dog's Performance Juxtaposition.* http://www.nwlink.com/~donclark/hrd/learning/memory.html. A concise and very general overview of scientific results and theories related to memory.

"Effective Memory Strategies." *The University of Western Ontario Student Development Centre.* http://www.sdc.uwo.ca/learning/memory.html. A short document describing strategies one can use to enhance their memory.

"Signs and Symptoms." *On Memory: A Caregiver's Guide to Alzheimer's Disease* http://www.memorytest.ca/english/index/default.asp?s=1. A short checklist people can use to assess whether they or a loved one are experiencing memory problems to a level that deserves medical attention.

"Using Memory Effectively." *Study Guides and Strategies*. http://www.studygs.net/memory. Another site providing tips on memory improvement, but this site does so within the context of studying for an exam.